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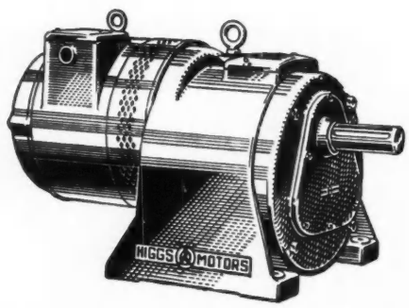

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THE STORY OF ATOMIC ENERGY.

VI.—ENERGY AND MASS : ISOTOPES.

By DR. FREDERICK SODDY, F.R.S.*

PART V dealt with the complete and satisfying explanation of radioactivity as a process of atomic disintegration in which energy is liberated a million-fold greater than from any source previously known. It is a part, though as we now know only a small part, of a till then unsuspected store latent in the atom and then only becoming evident when the atom changes. The word "then" is used advisedly. Its magnitude suggested that it was this source from which the sun and stars maintain their light and heat, and also amply explained why chemistry had been powerless to transmute the elements. From then on, the problem of releasing the primary sources of energy in the universe became the age-old problem of transmutation, the goal no longer useless

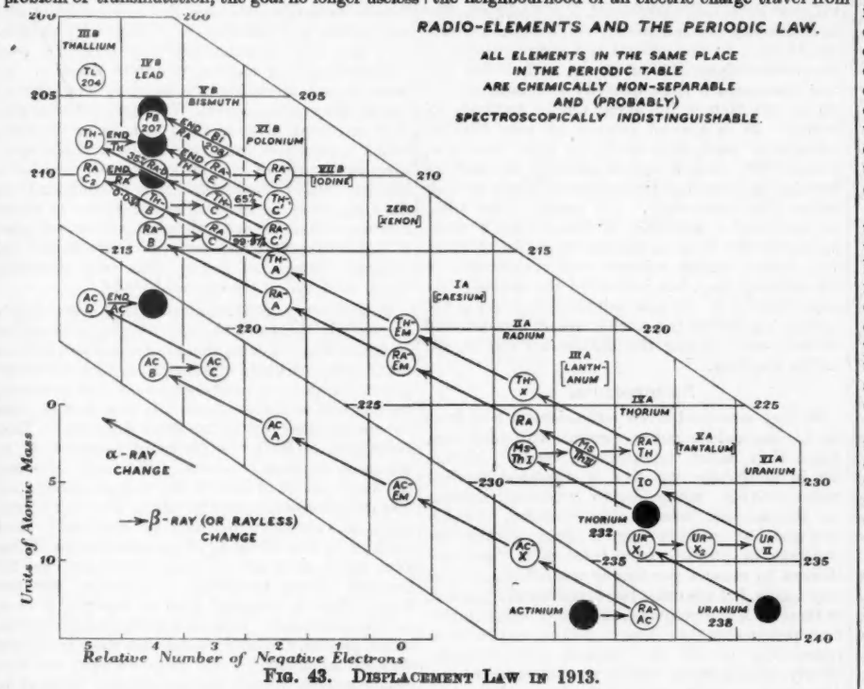


FIG. 43. DISPLACEMENT LAW IN 1913.

gold but the life-blood of all the animation of Nature, whether of living beings or of suns. The Philosopher's Stone, if in a very different sense from the perverted legend of alchemy, is also the Elixir of Life.

THE ELECTROMAGNETIC THEORY OF MASS.

One very pregnant result has not yet been dealt with, though it belongs to this initial period. It was the experimental verification for the β-rays of radium, by Kaufmann in 1902, of a strange prediction from the electromagnetic theory of light. This was, not only that an electric charge, if sufficiently concentrated, possessed inertial mass in the same way as matter, but that this mass is the greater the faster it moves. The theory made the mass become infinite at the speed of light, though at one-tenth this speed the increase is only one or two per cent., and, even at 99 per cent. of the speed of light, is only some three times the mass at rest. The electromagnetic calculations were approximations merely, in which different calculators got expressions different both from one another and from the simple formula later accepted; but Kaufmann's result established clearly enough this increase of mass with speed for the β-ray electron and showed that, over the range from 75 per cent. to 95 per cent. of the speed of light, the mass increased from 1·37 to 2·15 times that of the relatively slow-moving cathode-ray electron.

It is to be noted that this theory did have a purely physical foundation in the known laws of electromagnetism. One could visualise, for example, how electrical mass or inertia must accompany any movement of the electric charge. Faraday's electromagnetic field of force implies necessarily the existence of energy in some form, withal potential, in the space through which the force acts, and this field of force comes into existence only when the electric charge moves, since a stationary electric charge has no such electromagnetic field; so that before a charge can move, energy has to be spent on the surrounding space to build up this field of force, and before it can be stopped this energy has to flow back to the charge, resisting any change of motion, either increase or decrease, precisely in the same way as inertia does for matter. Now, on the electromagnetic theory of light, such changes in the neighbourhood of an electric charge travel from one place to another at the speed of light and, indeed, light itself is nothing but rhythmic changes of the electromagnetic field in the space traversed. But here we come up against the upsetting fact, experimentally established by Michelson and Morley in 1887, and repeated by the latter in 1905, that the velocity of light in all directions is completely independent of the rapid motion of the earth round the sun through the heavens. This is quite irreconcilable with ordinary ideas as to the motion of matter and how separate motions are additive in ordinary dynamics.

It must suffice here to say, without wishing to appear contemptuous, that it was reconciled by the pure mathematicians doing what by any one else would have been regarded as "cooking" the fundamental units of length, mass and time to make it so, a process known usually as the Lorentz transformation or, alternatively, the Fitzgerald transformation. The unit of length in the direction of motion is shrunk by a factor, less than unity, here called F, and the units of time and of mass are stretched by dividing by the same factor. This factor F is the square-root of the difference between unity and the square of the translatory velocity of the systems moving relatively to one another, expressed as a fraction of that of light. That is to say

$$F = \sqrt{1 - \frac{v^2}{c^2}},$$

where c is the velocity of light (3×10^{10} cm. per second), and v the relative velocity of the two systems. Thus F is unity for ordinary speeds and zero at the speed of light, which makes the length unit vanish and the time and mass units become infinite at the speed of light, which implies that no speed can exceed that of light. However, here it is rather the unit of mass with which we are most concerned.

THE THEORY OF RELATIVITY.

In 1905, Einstein began publishing his celebrated Theory of Relativity which made the result, already established for the electron, a general one for all inertial mass, whether electrical or material in nature. Before, the result, though sufficiently startling, had the prediction from electromagnetic theory to account for it. The obvious, if incorrect, deduction was that matter itself was of electrical origin, of which so much was heard in the first decade of this century under the name, the Electrical Theory of Matter. From the standpoint, even of the existing knowledge at the time, this was, properly speaking, no theory at all, but merely a woolly notion that, because electricity must possess inertial mass, matter must be built up out of electric charges. It left weight and gravitational attraction completely out, and it slumped together such widely different physical, chemical and transmutational changes, when matter loses negative electrons, as are caused respectively by rubbing resinous substances with flannel, in the formation of the positive ions of the electro-positive elements by combination with the electro-negative elements, and by the β-ray change in radioactivity.

The theory of relativity was independent of all theories of the nature of electricity and matter, and was the logical consequence of the speed of light being unaffected by the relative motion of transmitter and receiver. Its applicability was at first confined to minute astronomical events. It accounted perfectly for a slight, hitherto inexplicable, perturbation in the orbit of the planet Mercury, but the other predictions involved effects too small to allow of convincing verification, save to the already converted.

Einstein's starting point, however, was that all natural phenomena obey natural laws the nature of which is unaffected by uniform translatory motion, and, therefore, that this must hold good for the law of the conservation of energy. The Lorentz transformation, applied to this case, made the "cooked" value for kinetic energy the amazing expression $\frac{mc^2}{F}$, where m is the mass of the body at rest. It is more informatively expressed by the infinite series, into which it is transformed by the binomial theorem of algebra, only the first three terms of which are normally of significance.

Kinetic energy,

$$\frac{mc^2}{F} = mc^2 + \tfrac{1}{2}mv^2 + \tfrac{3}{8}\frac{mv^4}{c^2} + \tfrac{5}{16}\frac{mv^6}{c^4} + \ldots$$

The ordinary expression for the kinetic energy of a moving body is the second term of the series only. The subsequent terms are only of significance at velocities an appreciable fraction of that of light. But the first term is of colossal magnitude and is the same whether the mass is moving or at rest.

Had it not been for the prior knowledge of the existence of atomic energy, this first term would have been, as for long it was, interpreted as a mathematical constant merely, that is, as the zero or datum line from which the increase of kinetic energy with speed was reckoned, in order to formulate it as a function of the velocity. The prior discovery of atomic energy, however, endowed this first term with a possible meaning, that it represented the total internal energy in matter—a result so incredible and apparently outside of, and apart from, the argument by which it was derived—that certainly no experimental scientist could be expected to accept it without convincing proof.

THE ENERGY INTRINSIC TO MASS.

Hitherto, pure logic, which is what the theory of relativity is, had shown itself in science almost completely powerless to probe any of the deeper secrets of Nature unaided by induction and experiment. But this Einstein relation, if the first term is interpreted as the internal energy of mass, and therefore of matter, answers a question which,

* We have arranged with Dr. Soddy to publish his new book, *The Story of Atomic Energy*, in the form of a series of articles which are appearing at fortnightly intervals approximately. Dr. Soddy, however, retains the copyright, therefore no extract may be made from these articles without his permission.—ED. E.

before, the physical sciences had regarded as unanswerable by its very nature, namely, the total content of energy of anything and everything. Previously, all that it had been considered possible to know was the difference between the energy content of any system before and after undergoing any change, natural to, or imposed upon, it. But here, even the basic idea that energy and matter may be forms of the same thing had never before been dreamt of. Electricity and matter are still quite unconnected.

The Equivalence of Mass and Energy.

This is the celebrated Einstein Principle of the Equivalence of Mass and Energy which fuses the twin laws of conservation of mass and of energy into one law, and makes mass and energy mutually convertible. It suggested that matter might be capable of being totally changed into energy and annihilated as such, and, conversely, that matter could be produced by the disappearance of an equivalent amount of energy. Though still as far as ever from any real, or physical, as distinct from logical or mathematical, derivation, such as had led to the prediction concerning the mass of an electric charge and its increase with speed, what the principle affirms is simplicity itself.

In no change is either mass or energy alone conserved; in all change, if one changes the other changes also in the opposite sense. By giving the one an exchange value in terms of the other, it is the sum of both that is conserved. The C.G.S. unit of energy is the erg, making $m\,c^2 = 9 \times 10^{20}$ ergs per gram. That is the exchange ratio. The liberation of this quantity of energy accompanies the disappearance of one gram of mass, and vice versa. Expressed in heat units, it is twenty million million calories per gram. There are approximately a million grams to the ton. The energy liberated from the annihilation of a gram of matter is about as much as would be liberated by the combustion of some 4,000 tons of coal.

The change of mass, relatively to that of the energy, is so slight that for decades there was no possible test of this, by far the most amazing and important inference from the theory of relativity. In the total disintegration of uranium into lead and helium, neglecting the expelled electrons as relatively mass-less, the loss of mass, estimated from the output of energy, would be but one part in five thousand. In any chemical change it would be millions of times smaller. In Great Britain, the first to appreciate the physical significance of this inference from Einstein's theory seems to have been Sir J. J. Thomson in his 1914 Romanes Lecture at Oxford.

One example, often cited as practically a proven fact by imaginative astrophysicists, as it is at the moment the favoured theory of the origin of solar energy, is sufficient to show its general purport, though it is at present pure speculation, as only the disintegration, not the synthesis, of atoms has yet been experimentally observed. If, at solar temperature, four atoms of hydrogen were to combine or coalesce into one atom of helium, then, since for each gram of helium formed there would be a loss of mass of about $\frac{1}{118}$th of a gram, the energy evolved would be about equal to that from the combustion of some 32 tons of coal. It is as simple as that!

Here again, as with Mme. Curie, posterity may adjudge the Einstein Equivalence Law, great as it was, as not so great as the method by which it transpired. For he obtained by pure logical reasoning what before seemed impossible ever to find out, and to the writer, at least, that achievement seems to have no precedent in physical science. It also seems peculiarly appropriate that it was Sir J. J. Thomson who, by applying his 1897 technique to the accurate determination of the velocity, mass and charge of the positive rays of the vacuum tube, which Wien had shown to be due to positively charged ions, put into the hands of his able assistant, F. W. Aston, who improved it out of all recognition, the method by which this purely mathematical prediction was ultimately tested experimentally. Stranger extremes have never met, as will appear now we have to leave relativity and turn to consider isotopes. Before Aston died, towards the end of 1945, he had established in an impregnable position the doctrine of the equivalence of energy and mass as the guiding principle of transmutational change.

The Origins of the Conception of Isotopes.

Let us now turn to the obstinate world of different real things, and see how the conception of isotopes first arose. If a Biblical text is needed, it is to be found in "By their fruits ye shall know them," though no one would have guessed it applied not only to trees and men, but also to the elements; Lat. *elemens*, the *l*, *m*, *n*'s of the material alphabet. Any other definition would now be difficult.

Otto Hahn, who a third of a century later was to scale one of the pinnacles of immortal fame as having been the first to recognise atomic fission as a new type of atomic disintegration, worked as a research student (1905-7), first with Ramsay in London and then with Rutherford in Montreal. The new thorium-uranium mineral, thorianite, had just been discovered by the gemmers of Ceylon, and some hundredweights sent to Great Britain for investigation, curiously enough by the then science master of Eton College. By a very exceptional, if not solitary, error in a standard German treatise on chemical analysis, the thorium in the mineral had been mistaken in the first analyses for zirconium, and, before this was discovered a large quantity had been worked up in the factory by Mme. Curie's methods for radium. It is also of interest to note that no mistake had really been made, for, as we know now, precisely the same technical methods are used for working up thorium as for uranium minerals for their radioactive constituents. But instead of its being, as intended, a repetition of Mme. Curie's work, it proved also to be a parallel to it, for thorium. The radium-barium mixture was fractionated in the ordinary way, but instead of the radioactivity concentrating at the less soluble end, leaving the barium inactive at the soluble end, it concentrated at both ends leaving the barium inactive in the middle fractions.

Radiothorium.

So they separated a new radio-element both from the barium and the radium present, with great ease, which they called radiothorium, because, though not in ponderable quantity, it displayed thorium radioactivity in intense degree, producing thorium X, thoron, etc., exactly like thorium. Freshly prepared, by precipitating it from solution by ammonia in presence of a trace of a "carrier" element to cause a ponderable precipitate, it gives only α-rays, but the other two types rapidly develop, as thorium X is reproduced, the γ-rays being slightly more penetrating than those of radium, and the most penetrating of all the natural radio-elements. Clearly radiothorium was a new member of the disintegration series between thorium and thorium X, which Rutherford and the writer had not separated from thorium in 1901. What incompetent chemists it made us appear!

Thorium, being an important commercial element on which the incandescent gas-mantle industry is based, many chemists naturally immediately tried to separate radiothorium from thorium compounds. Its average life-period is some two years, so that while it lasted it would be as great a treasure as radium; but our failure was also theirs. There is not a chemist living who can do it yet, for radiothorium and thorium are chemically identical, or, as we now say, isotopic, though their atomic weights differ by four units, the mass of the α-particle expelled by the thorium atom in its first change.

Mesothorium.

The first to have the hardihood to ascribe their failure to natural impossibility, rather than incompetence, were McCoy and Ross, two American chemists who, in 1907, also suggested the correct explanation for its perfectly easy separation by Ramsay and Hahn. Before then, however, the latter, now in Montreal, had discovered that the radium from the less soluble end of the fractional crystallisations, which, of course, is derived from the uranium in the thorianite, contained another new radio-element. This new radio-element, in turn, grows radiothorium with lapse of time, and he named it mesothorium. Clearly, therefore, mesothorium is a new intermediate member between thorium and radiothorium. Actually, there are two mesothoriums. The first has an average life-period of nearly 10 years and does not give any obvious radiation in its change into the second, the period of which is only some 9 hours; so that, for many practical purposes, the two can be considered as acting as one. The important rays come from the second rapid change and comprise both β- and γ-rays, which are rather less penetrating than those of radium. But in course of time, by growth of radiothorium, it develops practically the whole radioactivity of the thorium in the mineral. Mesothorium is an important substitute for radium, and, mixed with zinc sulphide, it is used mainly for the luminous dials of watches and instruments, the useful life of the radioactive substances being longer than that of the zinc-sulphide phosphorescer.

Transmutational Analysis.

As McCoy and Ross first suggested, Ramsay and Hahn had not separated radiothorium from the thorium in the mineral, now as then an impossible feat. But, owing to the slow progress of large-scale factory operations, the mesothorium separated with the radium had had time to produce radiothorium, and this new radiothorium they separated from mesothorium and radium, not from thorium. No more elegant revelation of a secret so long kept by Nature has ever transpired. The thorium is changing into an isotope of itself via a member of the series which is separable from thorium, and so the spontaneous change of the radio-elements revealed a hitherto totally unsuspected type of complexity in the *l*, *m*, *n*'s of the material alphabet, due to simple mixture of two or more chemically identical types of substance. This may be termed transmutational analysis, though, of course, that only gradually began to dawn on the chemical world.

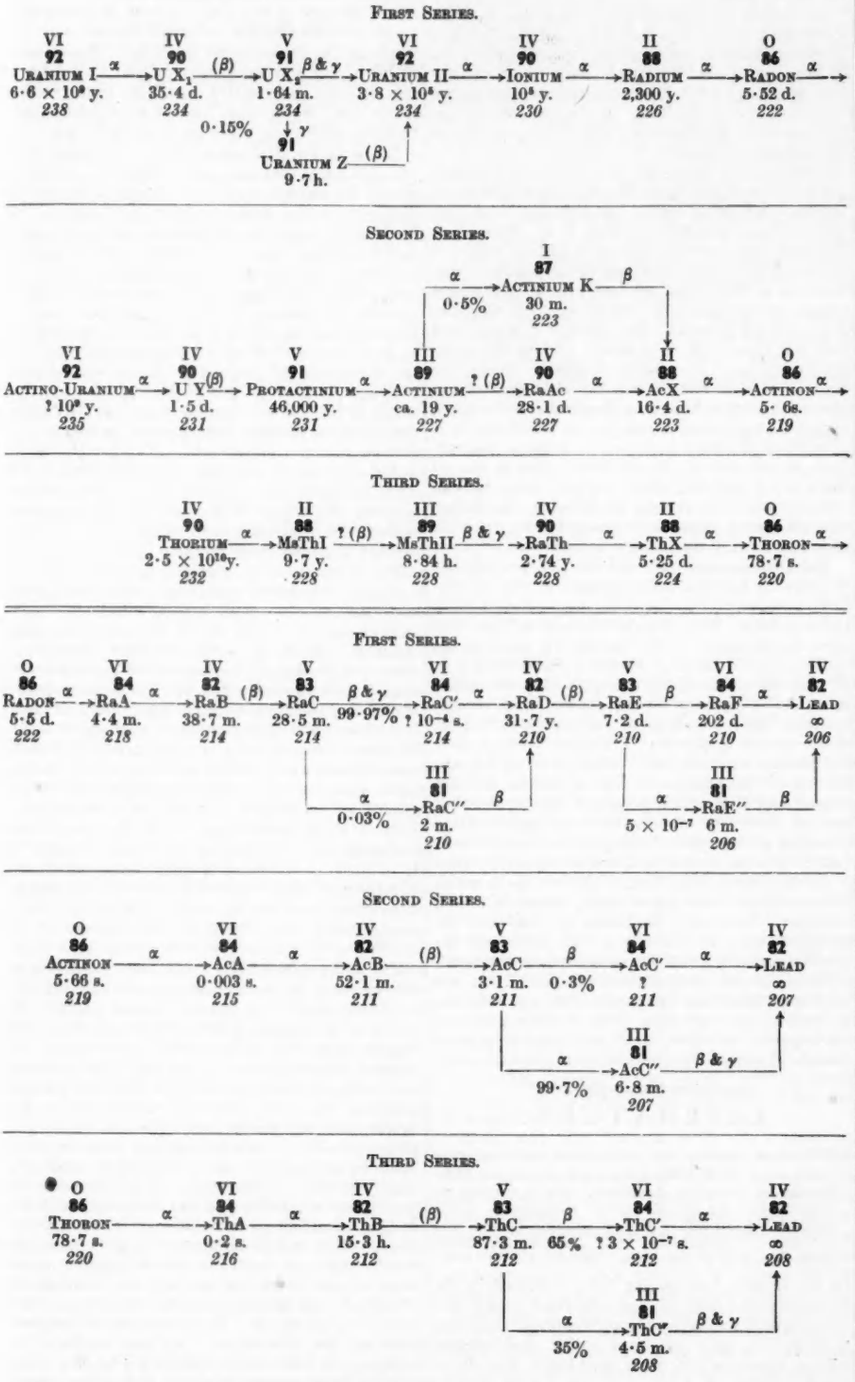
It has been mentioned already that, when finally unravelled, the three natural disintegration series comprise some 35 separate changes and therefore as many different kinds of atoms. As their discovery proceeded, the new members were not, like polonium, radium and actinium, chemically new, but isotopes of one another or of common elements. Thus radio-lead, or RaD, the parent of polonium, is, as its name suggests, chemically like lead; ionium, the direct parent of radium, like thorium, and so on. The *dénouement* occurred in 1910. The commercial value of mesothorium, already mentioned, had resulted in the methods of its manufacture being kept secret, as is still to some extent the case for thorium. Both Marckwald in Germany and the writer, then in Glasgow, tried to separate it from radium and failed. In a careful fractional crystallisation process, the latter found that there is not the slightest alteration in the ratio between the two radio-elements, though the barium may be, and is, thereby completely separated. This is the explanation of the fact mentioned, that the same methods serve to separate the radio-elements from minerals whether they contain uranium or thorium, or both elements.

The Displacement Law of Radioactive Change.

In 1911, the writer took the first step in formulating the Displacement Law of Radioactive Change which deciphered the Periodic Law. The expulsion of the α-particle causes a radio-element to move two places back in the Periodic Table, in the direction of diminishing mass. The passage through the Table for the disintegration series, however, is not straightforward, but alternates, so that the changing element reverts often to the same place as it had before occupied in the series. When this occurs, the product and parent in the same place have identical chemical properties, in spite of the difference in their atomic masses. The chemical character of the β-ray giving members of the series, or β-rayers, the life of almost all of which is quite short, had not then been sufficiently studied to enable anything to be said of them, and some, indeed, had been given a wrong chemical character.

Immediately, Alexander Fleck, then a demonstrator in the Physical Chemistry Department at Glasgow University, was asked to re-examine as many of the doubtful cases as their life-periods allowed from the point of view of finding out for each the element it resembled most, and then to see whether or not it was separable from that element. This

THE NATURAL DISINTEGRATION SERIES.



took some time and his results became well-known to several in the radio-chemical world long before they were published, through the perfectly free discussion encouraged in the laboratory of the results obtained by other past and present research students. Hence several besides Fleck share the credit for recognising the full Displacement Law, which became obvious in the spring of 1913, namely, A. S. Russell, a former research student, and G. von Hevesey, both then at work in Rutherford's laboratory at Manchester, and Kasimir Fajans, the pioneer in unravelling the branching of the series for the active deposits, then at Karlsruhe, Germany. Both the latter had specialised on the electro-chemistry of the radio-elements, which, however, had not been entirely trustworthy in elucidating their chemistry.

The Interpretation of the Periodic Law.

The complete Displacement Law proved to be of the simplest character, and to be obeyed without exception. It has become the foundation stone of the nuclear theory discussed later. For the expulsion of the β-ray causes the changing element to shift one place in the opposite direction to the shift of two places caused by the expulsion of the α-ray. Since many α-ray changes are immediately followed by two successive β-ray changes, frequently the great-grandchild comes back into the place occupied by its parent, and then is chemically identical with it, in spite of the difference of four in the atomic masses. From that time they were termed isotopes, or isotopic elements, meaning that they both occupied the same place in the Periodic Table.

Isotopes of two different elements may have the same atomic mass, and these are termed isobars. More rarely, isotopes of the same element may have the same atomic mass, but differ in stability, as by the one being radioactive and the other not. These are called isobaric isotopes, one example of which is mentioned at the end of this Part.

Since the α-ray carries two positive charges and the β-ray one negative charge, it was obvious at once that the Periodic Law was a relation between chemical character and the intra-atomic charge, not the mass. To-day the Periodic Law is *in extenso* the full expression of the atomic nature of electricity in the first place, and of a second and novel kind of atomicity, later to be gone into, when the Bohr theory of the origin of spectra is dealt with. Actually the first suggestion that unit-difference of intra-atomic charge characterises the successive places in the Periodic Table was thrown out by van der Broeck in 1911, but it was in somewhat cryptic language, and in conjunction with a wholly fanciful attempt to fit the numerous radio-elements into an old form of Periodic Table once suggested by Mendelejeff, with 120 places, the isotopes thus occupying different places.

The diagram, Fig. 43, on page 25, shows the original form of the Displacement Law in 1913. The vertical axis represents atomic weights and the horizontal axis the successive places in the Periodic Table, from the last, uranium, on the right, to thallium, on the left, now characterised by the atomic number, uranium being 92 and thallium 81, which is the serial number of the element in order in the Table, beginning with hydrogen as unity, helium 2, lithium 3, and so on. This is also the nuclear charge, or number of positive atomic charges on the atomic nucleus, and the number of negative electrons surrounding the nucleus. In the diagram this was represented as the relative number of electrons before the atomic number was known. The details of this diagram, which has been taken from a paper read in Section B (Chemistry) of the British Association, at the Birmingham Meeting in 1913, should be studied in connection with the complete up-to-date chart on this page.

This chart summarises as succinctly as possible our present knowledge of the three Natural Disintegration Series. The upper line gives the group number, and the next the atomic number, in the Periodic Table, of the radio-element, followed by its period of average life, and, in the last line, the mass number, *i.e.*, atomic weight, to the nearest integer. Each series has been broken into two parts at the zero emanation member, the better to bring out the analogies between the successive members. The symbol (β) indicates a very "soft" β-ray, of the same order of penetrating power as the α-rays. The case of UX_2 and UZ is unique in the natural, but now fairly well-known among the artificial, radio-elements. N. Feather interpreted it as due to the nucleus of the former being in an "excited" state. Some 0·15 per cent. of the atoms, before disintegrating, lose their excess energy and revert to "ground-level" by emitting a γ-ray photon, whereby the UX_2 changes into the isobaric isotope UZ, which disintegrates much more slowly than the UX_2 but is supposed to yield the same product, Uranium II. The same investigator, N. Feather, has just shown, 1947, that radium E probably undergoes a normal mode of branching, the minor branch here claiming only one in two millions of the atoms disintegrating. The very interesting normal 0·5 per cent. branching of actinium, in that the product of the minor branch, AcK, is in the hitherto vacant place No. 87, the highest homologue of the alkali-metals, was established by Mlle. M. Perey, a research worker in Professor Jean Perrin's laboratory in Paris, in 1939. Apart from these recent results the subject of multiple disintegration, as already indicated, lies beyond the scope of this story.

The Exceptions to the Periodic Law.

It had long been known that there were three exceptions to the Periodic Table, in that three pairs of elements were in reverse order of their atomic

weight, there being no doubt whatever as to their proper places. The case on which the issue was fought out was the pair, tellurium and iodine, but cobalt and nickel, argon and potassium are two other exceptions, and now protactinium, 231, and thorium 232, constitute a fourth exceptional pair. It has been mentioned in the Introduction that, on the O = 16 basis, about half of the chemical elements with the lightest atoms, for which, of course, the errors of determination are proportionally the smallest, have almost integral atomic weights. These were at once surmised to be pure, or single-isotope elements, the ones with atomic weights not integers being mixtures of isotopes of different atomic weight. This was vaguely suggested by Strömholm and Svedberg in 1909, and was brilliantly substantiated by Aston after the First World War. It resuscitated Prout's Hypothesis in a new form, and the discovery of the neutron in 1932 dealt the death-blow to the electrical theory of matter of the first decade of this century, though the latter played an important, if less fundamental, part in the theory of atomic structure now held.

Predictions from the Displacement Law.

We may now describe some of the important predictions from the Displacement Law, which were tested and immediately verified by experiment. Firstly, the uranium X of Sir William Crookes, which gives only β-rays, must, like mesothorium, undergo two successive β-ray changes. This was of interest because the first change brings out the uranium X from the place occupied by thorium into the vacant place between thorium and uranium. The duality of the change was almost at once established by Fajans and Göhring, but the second uranium X, which they termed Brevium, has a half-life of only a minute.

The Parent of Actinium. Protactinium.

But a second prediction referred to the parent of actinium, which must be an isotope of radium, if the actinium is produced in a β-ray change, but, if produced in an α-ray change, must be the missing element just mentioned between thorium and uranium. The first possibility the writer at once disproved, by testing an old preparation of Giesel's radium, which had been left undisturbed since manufacture, and in which actinium was completely absent. The second and more interesting alternative was then tested, with J. A. Cranston, using Brevium as tracer-element. After removal to Aberdeen in 1914, preparations so derived from radioactive minerals were found to be steadily growing actinium, thus proving the prediction. The element was simultaneously discovered by O. Hahn and Fräulein Lise Meitner in Berlin, who called it protactinium and, later, separated it from large quantities of the residues from the manufacture of radium from pitchblende.

It gives α-rays only, and the half-life is about 30,000 years. It is of interest as being the only one of the new radio-elements besides radium capable of being separated as a pure element. It closely resembles tantalum in its chemical character, but was brilliantly separated from this element by von Grosse. Its proportion in uranium minerals, however, is minute, in spite of its life being twenty times as long as that of radium, owing to its being not a product of the main isotope of uranium but of one present to an extent of less than one per cent., called, before it was certain that it existed, actino-uranium, which will be referred to again later. It is the isotope of uranium, now commonly known as U 235, which made an atomic bomb a possibility.

The Isotopes of Lead.

At the time, a third prediction that seemed the most important of all, was that the ultimate products of both uranium and of thorium must be two different isotopes of lead, of atomic mass 206 and 208, respectively, the atomic weight of common lead being 207·2. This was contrary to the opinion of the geo-chemists of the time, who had concluded that only uranium was responsible for the production of the lead in all uranium minerals. It afforded the possibility of putting the hypothesis of isotopes to conclusive proof by actually preparing two different kinds of lead of different atomic weight. Also, since isotopes differ only in having different nuclei in the same external electronic shell, the densities of the two leads should be proportional to the atomic weights.

As regards the thorium lead, the writer, in 1915, separated from the Ceylon mineral thorite, which is a thorium silicate containing only a small proportion of uranium, a lead of atomic weight and density corresponding to 207·7, one quarter per cent. higher than that of common lead. The atomic weight was confirmed by Hönigschmid, one of the experts in the subject, at Vienna, on a specimen supplied by the writer, who found 207·77. Next year, Fajans got a slightly higher figure for lead from a Norwegian thorite, containing rather less uranium than that from Ceylon. For uranium lead, T. W. Richards at Harvard, the greatest authority at the time on atomic weight determinations, Hönigschmid having been one of his pupils, got lead with atomic weight almost exactly 206 from certain very old thorium-free uranium minerals, the density of which lead was less than that of common lead in the same proportion as the atomic weights. These two isotopes of lead remain still the only ones of the heavy elements to have been obtained as individuals, except the two uranium isotopes, on which hundreds of millions of dollars were spent in order to separate them in the Second World War. That is due to their being produced over geological ages by two different elements, whereas the isotopic constitution of all the other elements is constant from whatever source or locality the element is derived.

The Displacement Law and the interpretation of the Periodic Law was contemporaneous with Rutherford's discovery of the atomic nucleus dealt with in the next Part. Both preceded the work of Bohr, who cited the Displacement Law in his first paper on the subject, and of H. G. J. Moseley, who extended it, by the aid of the Bohr theory, to the rest of the elements. Chemistry shared equally with physics in laying the foundations of our present knowledge of the nature of matter. There has been, in fact, a deliberate and calculated attempt to pervert the history of this chapter of science, and to make it appear that Rutherford, Bohr and Moseley, by their nuclear theory of atomic structure, explained the existence of isotopes and interpreted the Periodic Law; whereas in this field the theory merely gave a satisfactory explanation of known facts which are completely independent of any theory of atomic structure. Its novelty lay in the recognition of the atomic nucleus as the key to the theory of the internal constitution of the atom, and, at the hands of Bohr, in the interpretation of spectra. It was only much later that this explanation was extended to cover the peculiar form of the Periodic Law with its sequence of short, long and longest periods, already expounded in the historical introduction.

LITERATURE.

Records and Research in Engineering and Industrial Science. A Guide to the Sources, Processing and Storekeeping of Technical Knowledge, with a Chapter on Translating. By Dr. J. Edwin Holmstrom, B.Sc., A.C.G.I., A.M.I.C.E. Second edition, revised and enlarged. Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 21s. net.]

In his Rankin Lecture for 1938, delivered in the University of Liverpool, the late Lord Stamp said "I believe it would pay the profession (engineering) to have not only the most active card-indexes, science abstracts and other machinery, but also a number of 'watch dogs,' each with a dual training of engineering and another branch of science . . . to scout over the contiguous hinterland and draw special attention to possible sources of fruitful inquiry, experiment, analysis, or further research." In the present book, Dr. Holmstrom says "The division of science into 'subjects' is, of course, an arbitrary one which can only be justified by educational convenience . . . and a practising scientist, even though he cannot be personally familiar with more than a small territory of science, must be prepared at any time to make excursions into collateral regions to find what he wants." Lord Stamp did not deal with the question of the organisation and payment of a team of "watch dogs," but it would appear that the information services of the engineering profession would require much closer co-ordination than exists at present before a scheme of that kind could be put into operation on an extensive scale. The expense would be considerable. In spite of the large amount of money now spent on information services, almost the last words in Dr. Holmstrom's book are "the business of purveying and applying technical knowledge is not in itself a lucrative one," so that possibly competent "watch dogs" might want more money than the profession would be prepared to pay.

So far is Dr. Holmstrom from supporting Lord Stamp's suggestion that a new type of information officer, or service, is necessary, that he opens his preface with the statement that the "aim of this book is to teach the remarkable and stimulating fact that the whole of knowledge, except what is purposely kept secret, is available for everyone to use." His interesting and informative volume justifies this claim. There is no reason to suppose that he imagines present methods and organisations to be perfect and he points out, for instance, that the difficulties of keeping in touch with foreign technical literature "would be reduced by two-thirds if it could be regarded as part of the normal qualifications of every technician to be able to read English, German and French." This consummation is not likely to be reached in the early future, but even as things are, as this book shows, research workers and others have means at their disposal, if they like to use them, by which they can keep abreast of collective knowledge.

The book is not mainly concerned with the detailed technique of organisation in special libraries and information departments, although useful information is given about indexing and filing methods. What the author himself describes as the most important chapters in the book are concerned with the collection of data from technical literature; the sorting and integrating of facts and ideas; and their expression and transmission. In earlier chapters, accounts are given of research stations and research associations and of organisations, such as engineering institutions, which are essentially concerned with the collation of knowledge and its presentation. The chapters on the collection and utilisation of this knowledge, by individual workers or information departments, are of a practical character and furnish definite instruction about methods by which information officers may organise and present new information for the benefit of the technical workers whom they serve.

The early part of the book bears indirectly on the question of border-line information, inherent in Lord Stamp's proposed "watch dogs." By means of a diagram, it relates the activities of the various types of laboratories, associations and research organisations to the developing process by which scientific hypotheses and speculations gradually lead to practical applications. The overlapping of interests and activities which take place should do much towards ensuring that scientific advance, in almost any field, shall ultimately come to the knowledge of, and influence the proceedings of, those who are concerned with the design, manufacture and sale of machinery and plant. Much specific information is given about the constitution and activities of the greatly varied organisations which, in one way or another, are concerned with the development and application of scientific knowledge. In some detail matters, however, Dr. Holmstrom has not succeeded in bringing his information strictly up to date. The book was first published in 1940, and in this second edition the statement in the text that the "Water Pollution Research Board had, in 1938, no central laboratory of its own" is qualified by a footnote which states that "more recently, reference has been made to the existence of a Water Pollution Research Laboratory at Watford." This footnote relates to an article which appeared in June, 1945, but actually the Water Pollution Research Laboratory at Watford was established in January, 1940. Another example of the same class is furnished by the statement that the British Electrical and Allied Industries Research Association is located at Leatherhead. There are certainly hopes that it will be some day, but the probabilities are that this will not be before the appearance of the third edition of this able treatise.

THE ENGINEERING OUTLOOK.

II.—RETROSPECT AND PROSPECT.

THE first article in this series reviewed the general economic conditions affecting the engineering industry, and the part that it is expected to play in the Government's industrial and trade plans. In the present article an attempt is made to review statistically the industry's activity during the past year, and to appraise its prospects during the current year. This task is made extremely difficult by the fact that no comprehensive information is available concerning British engineering as a whole; for example, the net output of the industry (value added by manufacture) is not known, even by the Government. The results of the partial census carried out during 1947 will probably not be available until mid-1948, and, in the meantime, little is known concerning the capacity of the industry, the labour employed on each main product, the value of work in progress, the size of stocks of finished goods, and many other important aspects of engineering production. Without such data, it is difficult to conceive how the Government are in a position to plan engineering activity, to make far-reaching decisions concerning the future of the industry, to determine export targets, or to undertake to supply any one country with specified engineering goods by an agreed date. Planning on the basis of inadequate statistics is potentially dangerous, and, if planning there must be, it is of the utmost importance that relevant information should be accurately compiled and made freely available for all to judge the wisdom of the decisions taken. Evidence that the Government realise the inadequacy of the information at their disposal was supplied in November, 1947, by Mr. J. Wilmot, then Minister of Supply, when he intimated at a meeting of the Engineering Advisory Council that some statutory form of output return from individual concerns would probably be called for, as the present voluntary industrial census was insufficient.

The fuel crisis in February had a marked adverse effect on engineering production, resulting in the shutting down of a number of large works, and in constant interruptions through load-shedding by the electricity undertakings. The coal position has improved considerably since that date, and it is now unlikely that there will be a fuel crisis in 1948. Coal stocks held by public undertakings (gas, electricity and railways) stood at 7·59 million tons at the end of October, 1947, compared with 4·45 million tons at October, 1946—the equivalent of at least five weeks' supply at the peak rate operative in January, 1947. The chief danger appears to lie in the supply of coking coal. At the end of October, 1947, coke-oven stocks stood at 639,000 tons, whereas, during that month, the consumption amounted to 405,000 tons. Coke ovens, however, do not usually hold large stocks, and, during the war, stocks never reached 600,000 tons. Figures for the weekly average consumption of coal, and for coal stocks held by the iron and steel and engineering industries are given in Table I,* herewith, where they are compared with the corresponding figures for other industries and with the total inland consumption.

It will be seen that the consumption of coal by the iron and steel industry has declined steadily in recent years, from a weekly average of 217,000 tons in 1943 to 168,000 tons in 1947; a reduction of 22 per cent. This is probably due to extensive conversion to gas and oil firing. Even greater reductions have been made by the engineering industry—from 94,000 tons a week in 1943 to 53,000 tons in 1947. Since no reduction has taken place in other industries, and only a slight reduction in the total inland consumption of coal, and since engineering output was generally greater in 1947 than in 1946, the economies in coal consumption probably reflect large-scale conversion to oil firing and purchased electric power. To safeguard themselves against load-shedding by electricity undertakings, a large number of engineering firms have acquired mobile generating plant, which will play a useful part in easing the demand upon the grid. Moreover, the engineering industry was the first major industry to reach full agreement on staggered working hours; conditions of working and payment were agreed at a conference between the unions and the employers at the Ministry of Labour at the end of June, 1947. It can be expected, therefore, without undue optimism, that fuel will not prove a bottleneck in the production of iron and steel and engineering goods during the current year unless difficulty is experienced in transporting the fuel supplies from the pithead to the consumer. If danger exists, it will arise from the supply of inadequate quantities of coking coal, and the probable scarcity of oil fuel, which, for reasons of insufficient transport, storage and refining facilities, may cause embarrassment during next winter.

The Government's revised plans for capital expenditure, as outlined in the White Paper on *Capital Investment* (Cmd. 7268), published on December 1, indicate that the intense effort to secure adequate fuel supplies will be maintained. The demands for plant and equipment from the coal, gas and electricity industries will largely be met, and a programme for oil refineries, with an annual capacity of 20 million tons of oil at a total cost of 95*l.* million, has been approved in principle because of the potential saving in dollars. It has been recognised that the need to install as much additional electricity-generating capacity as possible during the next three years remains as urgent as ever. The revised programme should speed up the installation of new plant this year and in 1949, at the expense of reducing the capacity to be installed in later years. The programme for the modernisation and expansion of the gas industry, estimated to cost 34·4*l.* million this year and 36·3*l.* million in 1949 (at 1947 prices) for plant, machinery and buildings, should enable the industry to meet its minimum requirements. No effort will be spared to press on with the mechanisation of coal production, and mining machinery will almost certainly remain at the top of the fast-growing priority tree for steel allocation.

Steel was the limiting factor in engineering production during 1947, and, although the White Paper on capital investment in 1948 states that the iron and steel industry's expansion and modernisation programme is to go ahead—"the general conclusion must be that the maximum increase in the shortest possible time is required"—it is most unlikely that the steel supplies to the engineering industry during 1948 will be greater than in 1947. Competition for available supplies during the past year was so keen that it resulted in a breakdown of the Government's allocation system. Doubtless, the Government's plans to curtail capital expenditure will save substantial quantities of steel—for example, the limitation of the expansion of the electricity generating capacity to 1,500 MW a year, after 1949, will save 27,000 tons of steel in 1948 from plant being made for installation in 1950, and larger quantities later; the limitation of supplies of plant and machinery for home use will, it is hoped, save a further 68,000 tons of steel a year. Other savings will accrue from cuts in building and civil engineering programmes, and in the railways' capital investment programme.

All savings, however, will be directed to exports, where steel is becoming more and more an indispensable pre-requisite to the satisfactory conclusion of bilateral trading agreements. It is probable that the growth of bilateral trading—now recognised as the only practicable way out of the present chaotic world trading conditions—will increase the demand for direct steel exports. Primary producing countries are in desperate need of steel products, and are making supplies of food and raw materials conditional on their steel requirements being met; for example, Russia will only supply timber if Britain is in a position to provide steel rails and rolling stock for its transport from Siberia, the Argentine requires supplies of tinplate in which to pack food for this country, countries supplying textile raw materials require baling hoops, British oil companies operating in the Middle East must have sheets and tubes, etc. In some cases, a comparatively small tonnage of steel will safeguard important supplies for Britain, the lack of which may completely disrupt the national economy. Such considerations must be given due weight in determining the steel export policy at the present time.

The production of ingot steel is not likely to exceed 14 millions tons in 1948, although, to achieve this total, higher rates of output will be necessary in parts of the year. The Government's appraisal of the situation, is given in the *Capital Investment* White Paper, as follows: ". . . there is no immediate likelihood of any increase [in output] until new steel plants can be brought into operation. It is improbable that imports of steel will add very substantially to the supplies available. . . . The steel requirements of our export programme are not yet precisely calculable, and it is possible that, when the necessary trade agreements with other countries for the supply of our essential foodstuffs and raw materials have been made, even greater demands may arise for steel for export than are now contemplated. Furthermore, limitations in the supply of particular classes of steel within the general total may limit certain categories of home investment which require special types of finished steel."

There is reason to suppose that scarcity of special steels will also limit certain categories of production for export. This is another argument in favour of carefully balanced allocations to industry; the waste arising from unbalanced allocations during 1947 has been very serious. Recognising the inescapable fact that steel supplies are insufficient to meet the full-capacity requirements of the engineering industry, available supplies must be distributed so that they allow the efficient working of those sections of the industry which are most likely to produce the goods most urgently needed. This involves a smooth and assured flow of the right types of steel to the most efficient concerns, enabling them to produce to their full capacity at the lowest possible cost. To distribute steel supplies equitably can only mean that the majority of works will be working below capacity, and manufacturing costs will rise. As Sir Stafford Cripps pointed out in his statement to the House of Commons on December 18, buyers'-market conditions have already been reached in many lines of goods, and Britain is losing sales overseas because of high prices. It is of the utmost importance, therefore, that prices—particularly those of engineering consumer goods, such as motor cars, bicycles, refrigerators, and radio sets—should be prevented from rising further, and wherever possible should be reduced.

Figures for the supplies and consumption of raw steel (ingots and billets), as given in the *Monthly Digest of Statistics*, November, 1947, are shown in Table II, on page 30. The effect of the fuel crisis on output during the first quarter of 1947 was particularly severe, the annual rate falling to approximately

TABLE I.—STOCKS AND CONSUMPTION OF COAL BY MANUFACTURING INDUSTRIES.*

(Weekly Averages in Thousands of Tons.)

	Iron and Steel.		Engineering and Other Metal Trades.		Other Industries.		Total Inland Consumption.
	Consumption.	Stocks.‡	Consumption.	Stocks.‡	Consumption.	Stocks.‡	
1943	217	648	94	702	533	3,152	3,675
1944	198	701	87	736	515	3,184	3,602
1945	183	476	77	507	507	2,511	3,440
1946†	182	333	69	253	558	1,562	3,479
1947	168	759	53	725	534	3,829	3,446

* Undertakings with an annual consumption of 100 tons or more. † First ten months only. ‡ Stocks at the end of period.

* From the *Monthly Digest of Statistics*, November, 1947.

1½ million tons below the 1946 level. There was a good recovery during the second quarter. Output during the last quarter should exceed an annual rate of 14 million tons, provided that nothing unforeseen interferes with fuel supplies. In October, output was at the annual rate of 14·3 million tons.

The latest available information about the progress of the iron and steel industry's development plan was given in a paper on "The Iron and Steel Development Plan—Some Statistical Considerations," read to the Royal Statistical Society by Mr. R. M. Shone on May 22, 1947. The original plan, contained in a White Paper on *The Iron and Steel Industry* (Cmd. 6811, May, 1946), envisaged a total expenditure of 168*l.* million at 1945 prices. The schemes involved were to be started over a five-year period and completed in 7½ years. By the end of May, 1947, schemes totalling 140*l.* million* had been worked out in detail by the industry and had been submitted to the Iron and Steel Board for final approval. Approval in detail had been given to schemes totalling approximately 90*l.* million, which had been started and were in varying stages of progress. Certain further schemes had been generally approved by the Board, but were held up by housing and other problems. These brought the total value of schemes passed by the Board up to approximately 125*l.* million. The balance of the schemes submitted were still under consideration by the Board. It is impossible to guess how far the programme will be curtailed by the Government as a part of the general economy in capital investment, but it is probable that most of the major schemes already started—rather less than two-thirds of the plan—will be completed. The chairman of the Iron and Steel Board announced, on April 28, 1947, that the Board accepted the aim of the plan in relation to overall capacity, and also accepted the broad distribution of capacity set out in the plan. It may well be, however, that the scrapping of existing plant, as proposed in the plan (4 million ingot tons), much of which has still a useful life of a number of years, will be delayed in order to obtain the highest possible level of production pending the full completion of the plan.

TABLE II.—*Supplies and Consumption of Steel.*
(Annual Rates, 1,000 Tons.)

—	Production.*	Imports.†	Exports.‡	Available Stocks.§	Apparent Consumption.
1938 ..	10,392	816	1,692	—	9,516‖
1944 ..	12,120	1,382	208	1,684	13,781
1945 ..	11,796	156	578	1,224	11,834
1946 ..	12,684	312	2,028	1,068	11,124
1947—					
1st Qtr.	11,232	1,428	1,548	915	11,265
2nd Qtr.	12,648	1,524	1,668	855	12,564
3rd Qtr.	12,240	1,080	1,800	779	11,596

* Steel ingots and castings.
† Raw steel, including semi-finished and finished steel products, but excluding scrap.
‡ Exports of iron and steel products, excluding scrap, pig-iron, ferro-alloys, iron bars and rods, cast tube, pipes and fittings, railway wheels, tyres and axles and other railway materials.
§ At end of period.
‖ Consumption from stock in 1944 was 487,000 tons.

Among the main schemes already started is the new steelworks at Margam, in South Wales, with steel furnaces designed to supply a new continuous strip mill, which will produce approximately 1,000,000 tons a year of wide coiled strip as a basis for further continuous cold-rolling into tinplate and sheet. Site preparation work is well advanced and the first new blast-furnace in connection with the plant came into operation at the end of 1946. In Lincolnshire, extensions to the steel-melting shop of Messrs. John Lysaght, Limited, have been approved, together with the scheme for the construction of a modern continuous billet mill with a capacity of 450,000 tons of billets a year. Considerable progress has already been made, both on the steel-furnace and blast-furnace sides, in expanding production in preparation for the installation of the new mill. A new melting shop at the Appleby-Frodingham works has been approved and construction is well advanced. The modernisation of the heavy section mills at the same works is also proceeding.

The scheme for the erection of a new steelworks by Dorman, Long and Company, on the North-East Coast, has also been approved. This plant includes a universal beam mill to produce broad-flange beams, which should effect important economies in the weight of steel required for structural work. The rebuilding and enlarging of the Round Oak Works, based essentially on the scrap arising in the Birmingham area, has begun.

The proposed expansion of steel-furnace capacity in Northamptonshire has been approved in its general lines. In the original plan, provision was made for an increase in steel production in this area, the essential feature of which was that it should be based on home ores and would provide approximately 500,000 tons of billets a year, of which two-thirds would be available initially for outside sale. A detailed examination of the possibilities showed that the most rapid progress in reaching the objective would be by an extension on the site of the Corby works. A scheme has therefore been worked out by Stewarts and Lloyds, involving the expansion of production at Corby by rather over 700,000 tons of steel, mainly basic Bessemer quality, which will give the additional billets required for sale and also provide a basis for the expansion of tube production, made particularly urgent by the growing export demands.

Other major schemes have not the same urgency—except, perhaps, one for the rebuilding and enlarging of the steelworks associated with the continuous strip mill of John Summers and Sons, at Shotton, for sheet production.

The timing of construction has generally followed the line of priorities suggested as desirable in the plan. Priority has been given to a number of urgent schemes for developing output at existing plants where quick benefit would result. Some of the early benefits from the plan are already being realised from new blast-furnace capacity in South Wales, on the North-East Coast, in Lincolnshire, and in Scotland, and from new steel furnaces, particularly at the melting shop at the Appleby works in Lincolnshire. Benefits are also being derived from the steel-furnace oil-conversion programme, which will contribute in general to increased output from the plants as some offset to the increased cost of firing with fuel oil.

British engineering will undoubtedly reap increased benefits from the schemes outlined above, but it is most unlikely that enough steel of the right types will be produced to permit the full employment of engineering capacity, even by the end of 1949. Shortage of steel in the United States, where consumption greatly exceeds pre-war levels, may force Britain to shoulder overseas commitments, particularly in Europe, which will absorb all the increases in output that may be effected during the next two to three years, unless a deflationary movement takes place in the United States. A fall in the American demand for engineering consumer goods, for example, would free considerable quantities of finished steel, particularly rolled sections, sheet and forging steel, for export. There is no sign of such a movement at present, however, and it is much more likely that, during the coming months, the demand for steel in the United States will increase further, and that considerable pressure will be brought to bear on the United States Government by steel consumers to reduce drastically the supplies to Europe envisaged in the Marshall Plan.

The inadequacy of supplies of iron castings, which was one of the most serious obstacles to increased machinery production in 1946, continued during 1947, although the rate of production improved substantially. During the first nine months of the year, deliveries averaged 51,600 tons a week, compared with 47,100 tons in 1946. During September, deliveries averaged 60,800 tons a week, which represents an increase of 11 per cent. over the corresponding figure for 1946. The labour situation—the main cause of the industry's inability to meet demand—is much improved. The number employed increased from 124,091 in September, 1946, to 136,701 in September, 1947. The improvement has been steady over the whole of the past year, and there is little reason to doubt that it will be maintained during the current year.

The likely effects of the cuts in capital investment proposed in the White Paper on *Capital Investment in* 1948 were sketched in the first article in this series. It was pointed out that, although the cuts would make available substantial quantities of steel and engineering products for sale on export markets, they would do little to expand supplies for the engineering industry. The Government spokesmen have announced that any firm failing to sell their products abroad would be allotted less and less steel, but they have said little concerning possible measures to help industry to reduce its costs and thus to make successful selling easier. It has been suggested that export prices might be reduced by a devaluation of currency, but such a policy has many pitfalls, and at best can only be a stop-gap measure to gain a breathing space, and one to be applied as a last resort in the event of failure to reduce production costs. Talk about higher productivity of labour, more efficient manufacturing methods, etc., is of little avail if labour is under-employed in workshops all over the country. To await the correcting effect of the inability to sell abroad means slow death for hundreds of engineering concerns, a gradually falling output and rising prices. It also means widespread discouragement and a lowered industrial morale, which are hardly conducive to productive efficiency.

Another aspect of Government policy giving rise to serious concern is the determination to export plant and machinery that is urgently required for the re-equipment of British industry. Clearly, the present dependence of the country on engineering exports makes any other course of action difficult to conceive, but the attendant problems are real and serious. In the long run, it will prejudice the ability of British manufacturers to sell their goods overseas in competition with countries which have benefited from the import of up-to-date machinery from Britain. It will also retard progress towards higher productivity per man in British industry, and thus perpetuate the present acute labour shortage. There is probably a case for correlating the supply of materials with that of available new machinery, and for concentrating both in efficient productive units. This, however, would entail more controls, and the Government would be forced to discriminate ruthlessly in their allocations. Such a policy must raise, in an even more acute form than the present system of allocation, the whole question of who is to carry the loss sustained by private enterprise as a direct result of Government action.

Production statistics for the engineering industry as a whole do not exist. Available data concerning individual sections will be discussed in subsequent articles. Mention should be made here, however, of machine tools and electric motors in view of their fundamental role in expanding capacity and improving efficiency in the engineering industry in general. The machine-tool industry produced, during the first eight months of 1947, 28,865 metal-working machine tools, of which about 35 per cent. were exported. During this period, the industry was producing at the yearly rate of approximately 43,000 machine tools, valued at some 23·5*l.* million,

TABLE III.—*Electric Motors: Production and Exports by Value** (1,000*l.*), *January-October*, 1947 (10 *months*).

—	Production.		Exports.		Exports as per cent. of Production.	
*	1946.	1947.	1946.	1947.	1946.	1947.
Not exceeding ¼ h.p. ..	1,510	1,730	182	346	12·0	20·0
Exceeding ¼ h.p. but under 1 h.p. ..	960	1,540	113	271	11·8	17·6
From 1 h.p. to 250 h.p. ..	12,190	11,370	1,530	2,318	12·6	20·4
Total ..	14,660†	14,640	1,825	2,935	12·5	20·0

* Not including parts.
† Calculated on the basis of average monthly production for last six months of 1946.

* At prices then current. It was estimated that, since 1945, prices have risen by some 20 per cent. Schemes approved by May, 1947, would therefore amount to 112*l.* million at 1945 prices, or approximately two-thirds of the original estimate.

this figure being exclusive of spare parts. On the basis of war-time production figures, it is probable that the industry was physically capable of producing about twice that number. Deliveries of machine tools have been held up throughout 1947 by several bottlenecks in the supplies of ancillary equipment and materials. The shortage of electric motors is probably the chief limiting factor, followed by the shortage of ball bearings, steel, iron castings and labour, in that order. These limiting factors, which will be analysed in the relevant article on the machine-tool industry, are common to most sections of engineering, in varying degree, though not always in the same order of precedence.

The information available in respect of the production of electric motors is very incomplete, and generally is inadequate as a basis for any definite conclusions. Until June, 1946, deliveries of electric motors were published monthly, but were not separated into the main horse-power classes. From July, 1946, to the end of the year, no figures were published at all. Production figures are now available by value only, and will shortly be published. During the second half of 1946, the production of all types of electric motors averaged 1·47*l.* million a month. The corresponding figure for the period January to October, 1947, was 1·46*l.* million, a yearly rate of about 17·6*l.* million.

Production and export figures for the first ten months of 1946 and 1947 are set out in Table III, opposite. The analysis of the production figures was obtained on the basis of that of export figures, which provides a fair sample (about 20 per cent. of the total production). From this table, it will be seen that fractional horse-power motors are estimated to have accounted for about 22 per cent. of the total value in 1947—a somewhat lower figure than that given in various other estimates, some of which put it as high as 30 per cent. The most striking fact arising from these data is the high proportion of electric motors shipped overseas as direct exports, when the shortage of electric motors is known to be holding up vast quantities of other engineering products earmarked for export. An examination of the *Trade and Navigation Returns* for 1947 shows that 58 per cent. of total exports were shipped to British countries, the main customers being British India and the Union of South Africa. Large shipments to hard-currency countries were confined to Canada and Brazil, which together accounted for less than 8 per cent. of the total. It would appear, therefore, that the policy of allowing the direct export of one-fifth of total production should be reviewed in the light of the present serious shortage, which is endangering the export drive of many other sections of engineering.

The production of ball bearings (exclusive of production by direct Government contract) was at the rate of approximately 14*l.* million a year during the second and third quarters of 1947; of this, about 8 per cent. was sent overseas as direct exports. The yearly rate of imports during the same period was approximately 570,000*l.* In September, the industry employed 17,700 people, compared with 17,300 in April of the same year. Monthly production figures, however, do not show any upward trend, varying from 1·1*l.* million to 1·2*l.* million in the first nine months of the year. Only the most detailed and thorough analysis of the production of engineering components and ancillary equipment, such as pumps, springs, industrial valves, etc., would suffice to throw any light on the present involved situation. This cannot be done, however, for lack of relevant data.

The exports of engineering products during 1947 showed a marked improvement on the 1946 performance. The global value of exports of the main groups of the metal and engineering industries, given in Table IV, herewith, have been abstracted from the *Trade and Navigation Returns of the United Kingdom*. It will be seen that, though exports of iron and steel and non-ferrous metals were lower than in 1946, those of electrical goods, machinery and vehicles were considerably higher. The volume, value and destination of exports will be analysed in the concluding article of this series, when statistics for the whole of 1947 will be available.

TABLE IV.—VALUE OF EXPORTS OF SOME ENGINEERING PRODUCTS (1,000*l.*).

——	1938.	1944.	1945.	1946.	1947.*	1946 Value as Percentage of 1938.	1947 Value as Percentage of 1938.†
Iron and steel, and manufactures thereof	41,556	8,503	20,576	80,047	61,661	192	198
Non-ferrous metals and manufactures thereof	12,339	4,704	11,716	37,661	29,148	305	315
Electrical goods and apparatus	13,430	12,637	13,632	37,391	35,064	278	349
Machinery	57,868	40,960	44,609	113,800	129,422	197	299
Vehicles (including locomotives, ships and aircraft)	44,627	11,677	18,159	113,514	117,383	254	350

* First nine months.
† Calculated on a monthly average basis.

THE NICKEL INDUSTRY IN 1947.

IN a review of the nickel industry included in his customary year-end statement, Mr. R. C. Stanley, chairman and President of the International Nickel Company of Canada, Limited, states that world deliveries of Canadian nickel in all forms for the year 1947 were in excess of those of 1946, although considerably below the war-time peak reached in the year 1943. Canadian nickel deliveries last year, in all markets, approximate to those of the industry's greatest peace-time year of 1937, and shipments in the United States and Canada show an increase of about 50 per cent. over those for 1937. Operations at Copper Cliff, Ontario, Canada, the company's mining and smelting centre, were on a substantially higher scale than in 1946, despite a continuing labour shortage. The largest consumer of nickel during 1947 continued to be the steel industry, and the production of nickel-chromium stainless steels in the United States accounted for a considerable portion of this consumption. The applications of nickel-containing stainless steels in the various industries continue to be numerous and diversified, and the chemical, petroleum and transportation industries remain important users of stainless steels.

The so-called triple alloy steels, containing nickel, chromium and molybdenum, continued to be extensively employed last year, particularly in the internal-combustion engine, constructional, railway, tractor and machine-tool industries. Their aggregate tonnages, as in 1946, were again the largest of any single class of engineering alloy steels. Two notable applications of comparatively recent origin for these materials comprise structural "aircraft" tubing, and hot-coiled and leaf springs for railway, motor-car and tractor uses. Nickel-chromium and nickel-molybdenum steels of the pre-war standard types have also resumed their leading positions in industry. Of great interest is the growing utilisation of high-strength low-alloy steels. The majority of these steels contain nickel and now contribute materially to the total consumption of nickel by the steel industry. It is expected that, as more consumers become familiar with the savings accruing from structures made with these steels, their use in place of carbon structural steels will increase. Increases in the use of heat- and corrosion-resisting cast steels for industrial applications have continued.

Post-war activities, both in the United Kingdom and elsewhere in Europe, point to a continuance or an extension of the use of nickel-alloy steels. A matter of interest in this connection is the extensive use of nickel steels in the British Railton Mobil Special racing car, which exceeded a speed of 400 miles an hour at Bonneville Salt Flats, Utah, in September. Nickel steels are being employed in lightweight tractors which are particularly important to United Kingdom agriculture. The new Rolls-Royce piston-type engine, one of the most powerful aircraft engines of its kind, makes extensive use of nickel steels and other nickel-containing materials. On the Continent, where war-time controls resulted in the employment of "ersatz" alloy steels, nickel-alloy steels are once more taking a prominent part in the new steel specifications. Lightweight nickel-alloy steel mine cages for collieries have proved very successful in Belgium and further cages are being constructed in that country and in France.

The past year saw a further extension in the use of Monel, Inconel, and other nickel alloys, as well as rolled nickel, for special-duty purposes involving resistance to heat, corrosion, wear and other difficult conditions. The rapid advances in jet engines accounted for an increase in the use of Inconel on account of the ability of this high nickel-chromium alloy to withstand high temperatures and corrosive gases. The same alloy has also assumed further importance for heat-treating equipment. The Nimonic alloys, particularly Nimonic 80, continued to be the standard turbine-blading material for all British jet-propulsion engines. These alloys, developed by the Mond Nickel Company's development and research department, are employed for this application because of their high creep-strength properties at red-heat temperatures. In the United States, the International Nickel Company have developed another high-temperature alloy, Inconel X, which is being used experimentally for gas-turbine wheels, forged turbine blades and sheet metal applications for jet engines.

One of the standard uses for Monel, for more than a quarter of a century, has been on board ship, for applications ranging from pump parts to boiler equipment, and the conversion, in the United States, of war-time vessels to peace-time use has continued to provide an outlet for this nickel-copper alloy. Chemical and food industries in Great Britain, France and Belgium have placed substantial orders for pure nickel, Monel, Inconel, and nickel silver. The applications include caustic-soda equipment and large salt driers. Further developments have taken place with nickel-clad steel, particularly in connection with the soap industry. The expanding field of electronics has brought many new uses for nickel and nickel alloys, and there has been also an important growth in the use of nickel-chromium electrical resistance materials. The increasing utilisation of electrical energy for domestic appliances, water heaters and ranges has been largely responsible for this. The high post-war demand for nickel by wrought copper-base alloy manufacturers has continued. The nickel-silver alloys are expanding their markets as base metals in the silver-plated tableware field, and for springs in electrical and telecommunications equipment. The 70-30 cupro-nickel alloy has proved of value as an alloy for heat exchangers and is now being more widely employed in marine and coastal installations, power stations, and the petroleum industry. Cupro-nickel for condenser tubes, and other nickel alloys for various purposes, continue to be employed in the large shipbuilding programme now in hand in the United Kingdom.

Progress in the field of nickel-alloy cast irons has been well maintained during 1947. Sales of nickel during the year, for the production of Ni-Resist, are expected to be 45 per cent. greater than was the case in the best previous peace-time year, and Ni-Hard production, exclusive of rolls, will utilise nearly 90 per cent. more nickel than was consumed in any previous year. In addition to very satisfactory progress in the development of Ni-Hard in the mining fields of the United States and Canada, this abrasion-resisting alloy is being applied in South America, Mexico, South Africa and India, for grinding, milling and other mining applications. In Great Britain, as in the United States, most of the rolls for rolling mills now contain nickel. The International Nickel Company, in their constant search for new mineral deposits, have employed the airborne magnetometer which is revolutionising prospecting methods. The essential part of this instrument is a magnetic detector utilising a high-permeability nickel-alloy core that is periodically saturated. The changes in the intensity of the earth's magnetic field alter the output from this component and are continuously recorded, making possible the detection of magnetic anomalies in the earth's surface.

Although the volume of nickel consumed for plating purposes in the United States in 1946 constituted a high record, and the total included purchases for re-equipping the facilities of the plating industry, sales for 1947 were higher still and are a more correct indication of the increased consumption of nickel for plating. The motor-car industry is still the largest consumer, although the demands from all other fields have increased. Steel pipes lined with electro-deposited nickel, which is a war-time development, have aroused considerable interest. More attention has been given to methods of salvaging worn and overmachined parts by building them up to size by nickel-plating. Research on methods of nickel-plating aluminium has continued during 1947. This will expand and diversify the applications, which are largely confined, at present, to domestic appliances and plumbing details. Plastic and other non-metallic components having a nickel deposit combine increased rigidity and strength with lightness of construction. In addition, the nickel provides resistance to abrasion and to moisture absorption. Finally, it may be stated that nickel-anode consumption is being maintained on a steady high level in the United Kingdom, being about twice as great as in pre-war times.

PROPELLING MACHINERY OF M.V. "FULHAM VIII."

THE Fulham Corporation's new collier, Fulham VIII, recently completed by Messrs. Burntisland Shipbuilding Company Limited, Burntisland, Fifeshire, is of interest owing to the unusual arrangement of the propelling machinery. The vessel has a deadweight capacity of 2,630 tons, and the propelling machinery has been designed to give a mean speed on trial of 11¾ knots when fully laden. This consists of two 12-cylinder V-type Diesel engines arranged to drive a single screw through hydraulic couplings and a reduction gearbox, and it is understood that this is the first installation of this type to be fitted to a British collier. Before describing the machinery in detail, however, it might be advantageous to give a brief description of the vessel. As the name implies, the Fulham VIII is the eighth vessel to be built at Burntisland for the transport of coal to the Fulham Borough Council's electric power station. Like her predecessors, she has been designed to navigate the River Thames, and, therefore to pass under a series of low bridges. The vessel is of the raised quarter deck type and has a length between perpendiculars of 260 ft., the breadth and moulded depth being 39 ft. 6 in. and 18 ft. 9 in., respectively. There are three large cargo holds built on the Burntisland hopper principle which allows the coal to flow by gravity to within range of the discharging grabs. The hatchways are fitted with steel covers and the deck machinery includes a hauling winch for operating them.

As already mentioned, the main propelling machinery consists of two heavy-oil engines arranged to drive a single screw through hydraulic couplings and reduction gearbox. An impression of this arrangement can be gained from Fig. 1, on this page, which shows the engines and ancillary components erected on the test bed at the Hazel Grove Works of Messrs. Mirrlees, Bickerton and Day, Limited, Stockport. Each engine is coupled through a David Brown cone-ring flexible coupling to a Vulcan-Sinclair scoop-controlled hydraulic coupling, the driven members of which are, in turn, connected to double-helical pinions and these mesh with a common gear wheel, as shown in Fig. 2, which shows the gearbox with the cover removed. The normal rating of each engine is 820 brake horse-power at 600 r.p.m., while the gearbox ratio is 5·1 to 1·0 and, allowing for 2·5 per cent. slip in the hydraulic couplings, the maximum speed of the propeller is 114·7 r.p.m.

The two engines have been supplied by Messrs. Mirrlees, Bickerton and Day Limited, and each is a 12-cylinder, 35 deg. V, supercharged four-stroke heavy-oil engine, having a bore and stroke of 8½ in. and 13¾ in., respectively. An illustrated description of this type of engine will be found in ENGINEERING, vol. 161, page 560 (1946), so that only a brief description need be given here. The crankcase is cast in two parts, the upper part carrying the cylinders. The cylinders are each separate castings with lugs for bolting to the crankcase, and they are fitted with wet-type liners. The cylinder heads also are separate castings and these are fitted with the air-inlet and exhaust valves which are operated in the usual manner through push rods and rocking levers. There are two inlet and two exhaust valves for each cylinder, operated by two separate sets of cams, one for ahead and one for astern running. A separate fuel pump is provided for each cylinder and these are fitted to the upper half of the crankcase. They are operated directly from the camshaft, two cams being provided for each pump, for ahead and astern running, respectively. Each engine is controlled by a single handwheel for stopping, starting and speed variation, while it is reversed through a small hand-operated lever. This admits air to a pneumatic cylinder, the piston of which moves either to the ahead or the astern position, according to that selected, and the appropriate cam followers are brought into contact with the camshaft through a connecting linkage. Starting air is provided by an air compressor built into each engine and driven from the forward end of the crankshaft. The compressors are of the two-stage differential type and will charge a receiver having a capacity of 23 cub. ft. to a pressure of 300 lb. a square inch in 23 minutes; four receivers of this type are provided.

Bilge pumps and circulating pumps are driven from the forward end of each engine; these are of the ram type, the bore and stroke being 5¼ in. and 3½ in., respectively. The pumps are identical, and a suitable system of change-over valves is provided so that the bilge pumps can operate as the circulating pumps. Two oil pumps are fitted, a pressure pump and a scavenge pump. The latter draws the oil from the engine crankcase and delivers it to an external tank, while the pressure pump delivers the oil through a Serck oil cooler to the engine bearings, etc. Provision is made for reversing the duties of the pumps, and, in an emergency, the engine can operate with only one pump, in which case the oil is drawn from the crankcase and delivered directly to the engine. A hand pump is provided so that the lubricating system may be primed

MACHINERY OF M.V. "FULHAM VIII."

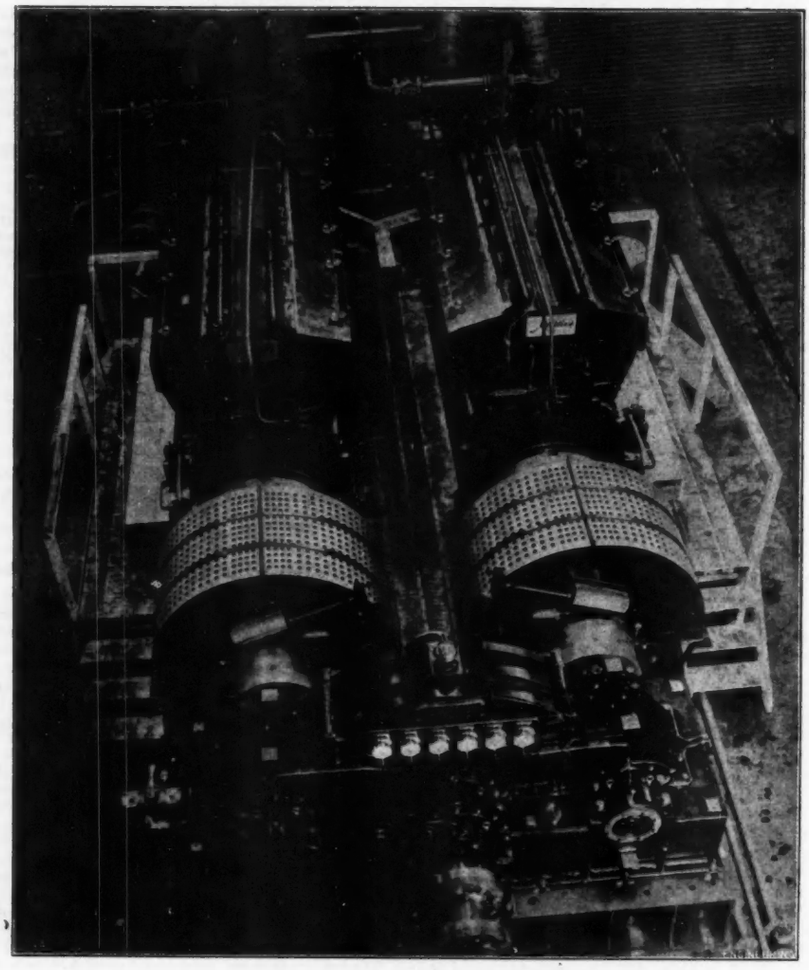


FIG. 1. ENGINE INSTALLATION ON TEST BED.

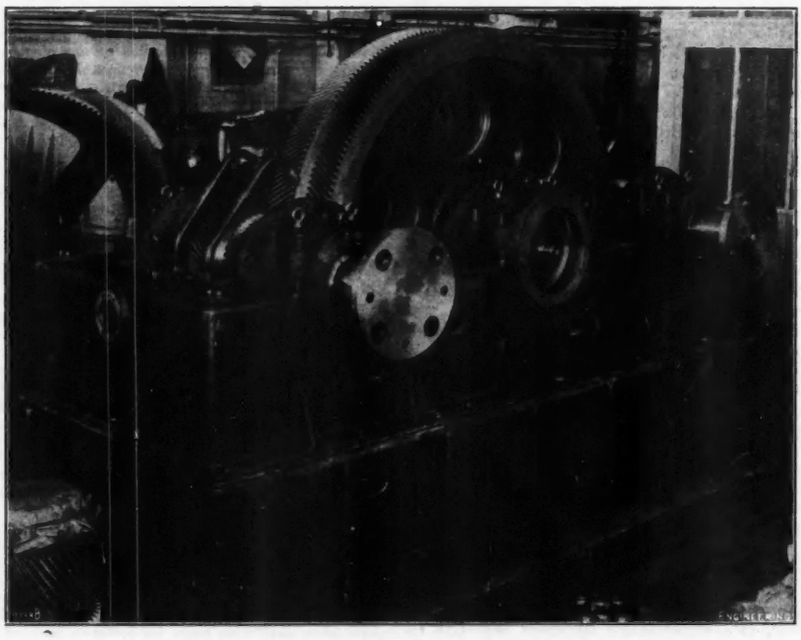


FIG. 2. GEARBOX WITH TOP COVERS REMOVED.

MACHINERY OF M.V. "FULHAM VIII."

Fig. 3.

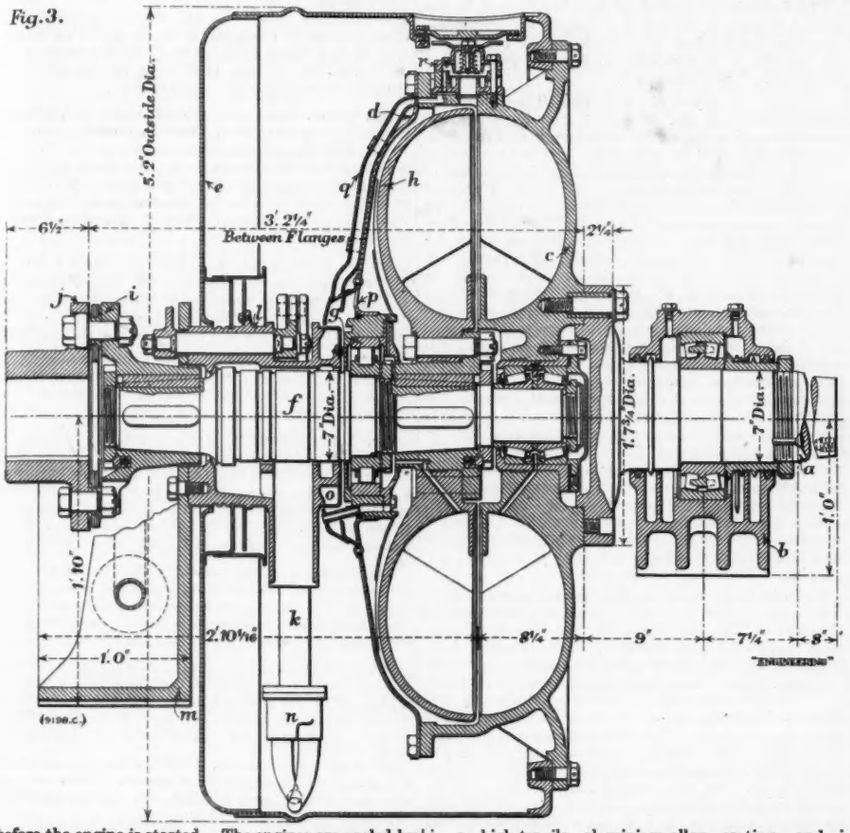
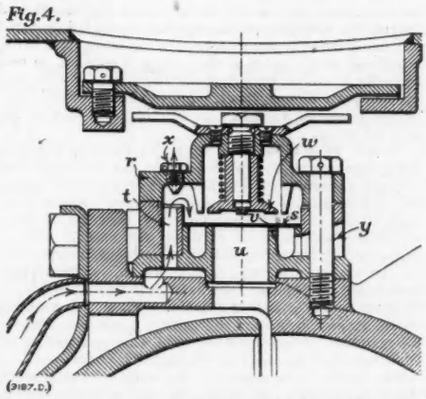


Fig. 4.



before the engine is started. The engines are cooled by fresh water, two heat exchangers being provided, one of which acts as a stand-by. Each heat exchanger is suitable for cooling 9,000 gallons of fresh water an hour from a temperature of 150 deg. F. to a temperature of 120 deg. F., with a sea-water flow of 8,900 gallons an hour and a sea-water temperature of 70 deg. F.

The hydraulic couplings have been built by Messrs. Hydraulic Coupling and Engineering Company Limited, Isleworth, Middlesex, and, as previously mentioned, they are of the Vulcan-Sinclair scoop-controlled type. They have been designed for use with the Mirrlees engines and, at full load and speed, each coupling will have an output speed of 585 r.p.m. with an engine speed of 600 r.p.m., the slip, therefore, being 2½ per cent. The maximum and minimum governed speeds of the engines are 600 r.p.m. and 230 r.p.m., respectively, and within this range the speed of the propeller shaft is controlled by regulating the speed of the engines. Propeller speeds below that corresponding to the minimum governed speed of the engines, however, are obtained by operating the scoop controls of the hydraulic couplings, by which means, infinitely-variable speeds over the range of approximately 5 to 1 can be obtained.

The mechanical construction of the coupling comprises an input shaft supported in a self-aligning bearing, a scoop-controlled coupling with a rigidly-mounted runner-shaft and a multi-disc flexible coupling on the output shaft. This form of construction is shown in the drawing reproduced as Fig. 3, on this page, which is a sectional elevation through the centre of one of the couplings. The input shaft *a* is a solid forging of high-grade steel and has fitted to it a Skefko self-aligning roller bearing, which is supported by the pedestal *b*. The after end of the input shaft is flanged, and the impeller *c* is held to the flange by eight steel sleeves which are retained in position by set bolts. The impeller is an iron casting and it supports, from flanges formed on the periphery, the inner casing *d* and the outer casing *e*. The centre boss of the impeller acts as a housing for a set of opposed Timken roller bearings and these, in turn, support the forward end of the output shaft *f*, thus allowing for all possible fluctuations of thrust likely to be set up in the coupling. The main roller bearing *g* for the output shaft, however, is located within a housing welded to the inner casing *d* of the impeller, and it will be seen, therefore, that this form of construction ensures that the coupling output shaft forms a rigid prolongation of the axis of rotation for the coupling casing. The runner *h* is a high-tensile aluminium-alloy casting, and is bolted to a forged-steel hub which, in turn, is keyed to the forward end of the output shaft. The after end of the output shaft has keyed to it the half coupling *i* and this is connected, through a flexible disc and the corresponding half coupling *j*, to the gearbox pinion shaft. The inner and outer casings are fabricated from mild-steel plate and the outer casing is designed to accommodate in its lower half the full quantity of oil when the coupling is stationary. Therefore, no glands are fitted but labyrinth seals having large clearances are provided.

The scoop *k*, which controls the amount of oil in the circuit and, therefore, the torque transmitting capacity of the coupling, is carried by a fixed housing *l* which surrounds the output shaft; the fixed housing, in turn, is bolted to the pedestal *m*, situated outside the coupling. The scoop is made from solid-drawn steel tubing and in view of the fact that the main engines are reversible, it is constructed so as to accommodate the reversals in the direction of rotation. The main body of the scoop *k* slides within the housing in a vertical direction, and terminates at its lower end in a flange to which is connected the valve housing *n*. The latter is a gunmetal casting and takes the form of a breeches piece, carrying two scoop tips pointing in opposite directions and arranged to line up with a groove in the outer casing. The valve consists of a hardened-steel ball which seats itself automatically on the mouth of the scoop tip which happens to be trailing, according to the direction of rotation. The complete scoop unit is raised or lowered through a simple lever mechanism, the external component of which is connected to a remote control by a suitable linkage. The scoop housing *l* is a symmetrical iron casting and, in addition to acting as a support for the scoop, is provided with the necessary ports for transmitting the oil through an external circuit and then into the coupling. The object of passing the oil through an external circuit before it enters the coupling is to allow an oil cooler to be fitted if found necessary in service.

The scoop, as previously mentioned, is used to vary the amount of oil in the coupling and therefore its torque-transmitting capacity. With the engine running and the coupling transmitting no load, the scoop will be fully withdrawn and all the oil will be held in the outer casing in the form of a rotating annulus. When the scoop is lowered into the internal surface of the rotating annulus, the oil will flow into the tip of the scoop and then, by way of the body of the scoop and suitable ports, into a horizontal duct formed in the housing *l*. The oil then passes through the external pipe referred to previously and returns through a further duct in the housing to the annulus *o*. Thence, the oil flows through circumferential slots formed in the periphery of the annulus *o* into the coupling through the ports *p* and through the tube *q* to the quick-emptying valves *r*, there being three of these valves spaced at 120 deg. to each other on the periphery of the coupling. A view of one of these valves to a larger scale is given in Fig. 4, on this page, and their function is to ensure quick response to scoop operation and therefore, speed control. Each valve is of the diaphragm type and it will be seen from Fig. 4 that the space above the diaphragm *s* is connected by the channel *t* to the tube *q*, while the underside of the diaphragm is in direct communication with the oil in the coupling through the opening *u*. When the coupling rotates, the pressure due to centrifugal force will be approximately equal on both sides of the diaphragm, but owing to the fact that the top of the diaphragm presents a greater area to the oil, it will be held to its seating *v*. It should be emphasised at this juncture that the spring-loaded plunger *w* has no connection with the normal operation of the valve and its function will be explained later; so long as the coupling rotates it will be held by centrifugal force in the position shown in Figs. 3 and 4. There is a constant leak-off of oil from the nozzle *z*, but as soon as this oil reaches the outer casing, it is returned by the scoop to the tube *q*, thus ensuring that this tube is continuously charged with oil when the scoop is in operation. If the scoop is raised, however, the oil above the diaphragm will leak off without being replenished and the pressure above the diaphragm will fall to zero. The diaphragm, therefore, will lift from its seating and allow the oil to drain away from the coupling through a series of ports formed in the valve housing, one of which is shown at *y*. Obviously, if the scoop is only partly withdrawn towards its innermost position, the oil will flow from the coupling until the surface of the rotating annulus of oil within the casing comes into contact with the tip of the scoop in its new position, at which instant the oil will flow into the valves and return the diaphragms to their seats.

It will be realised, therefore, that the amount of oil circulating in the coupling, and consequently its capacity for transmitting torque, depends on the position of the scoop. When the scoop is engaged fully, all the oil is kept in the coupling and approximately the full torque of the engine is transmitted; but when the scoop is withdrawn to its innermost position, all the oil drains into the outer casing and no torque is transmitted. Between these two extremes, however, infinitely-variable speed regulation can be obtained over a range of approximately five to one.

The gearbox is a double-pinion marine reduction type built by Messrs. David Brown and Sons (Huddersfield) Limited. The unit is illustrated in Fig. 2, opposite, where it is shown with the top cover removed, and it will be seen from this illustration that double-helical gears are fitted. Each pinion has 43 teeth and is forged solid with the input shaft from heat-treated nickel-chrome-molybdenum steel. The wheel has 219 teeth and consists of a rim of heat-treated carbon-nickel steel which is shrunk on and pegged to a cast-iron centre, the centre being pressed on and keyed to the output shaft. The rim, centre and shaft were assembled before the teeth were cut so as to ensure concentricity of the teeth and shaft. Both the pinion and main shafts run in forged-steel white-metal lined bearings. The propeller thrust is taken by a Michell thrust-bearing incorporated in the after end of the gearbox and capable of transmitting a thrust of 32,600 lb. The casing is of fabricated-steel construction, the lower portion serving to carry the forged-steel bearings, while

the top is constructed in three portions. The bearing caps are bolted and dowelled to the lower portion of the case independently, thus enabling each bearing to be examined without disturbing other parts. Forced lubrication is employed throughout, the oil being stored in a sump fitted to the underside of the casing and being circulated to the gears at the points of contact, as well as to the bearings, by a pump driven from the after end of the port pinion shaft. An auxiliary electrically-driven pump is provided for starting and also to act as a stand-by.

It will be obvious that with this form of gearbox, when one engine is shut down and the corresponding scoop withdrawn, the output shaft from the coupling, and, therefore, its runner, will be turned by the other engine, and if oil is allowed to flow into the coupling an appreciable amount of drag will occur. This is prevented by the spring-loaded plungers *w* incorporated in the quick-emptying valves, which, as previously mentioned, are held in the position indicated in Fig. 4, so long as the coupling rotates. When the coupling comes to rest, however, the springs move the plungers into contact with the diaphragms, thus preventing oil from entering the coupling through the ports *y*.

The main advantage of the engine arrangement described above is, of course, the ease of manœuvring. As previously mentioned, the engines are started and reversed by compressed air and the propeller shaft revolutions between the maximum and minimum governed speeds of the engines are controlled by regulation of the fuel supply in the usual manner. The hydraulic couplings are regulated by air servos linked to the engine control wheels and are arranged so that when the engines are stopped the scoops are fully withdrawn. When the engines are started, however, and the control wheels are moved towards the slow-speed position, the scoops are moved out to their full extent and will remain in this position until the engine control wheels are moved to their neutral positions when they will be fully withdrawn. Propeller speeds below that equivalent to the minimum governed speeds of the engines are obtained by operating handwheel controls adjacent the couplings; these over-ride the air servo cylinders and withdraw the scoops, thereby allowing a propeller speed equivalent to engine speeds of 50 r.p.m. to 60 r.p.m. to be obtained. For close manœuvring, the engines are run in opposite directions, with both engine control wheels set at neutral, in which position the scoops are fully withdrawn. A small movement of either engine control wheel in the increased-speed direction operates the air valve and moves that particular scoop to its full extent, thus giving either ahead or astern running. For warming up, the engines are run at minimum speed with the engine control wheels set at the neutral positions.

LAUNCHES AND TRIAL TRIPS.

S.S. "SIR GORDON II."—Twin-screw tug built and engined by Messrs. Ferguson Brothers (Port-Glasgow), Limited, Newark Works, Port-Glasgow, to the order of the Crown Agents for the Colonies, Millbank, London, S.W.1, for service in the Gold Coast. Triple-expansion engines with one oil-fired multitubular boiler on the Howden-Wallsend system. Launch, December 18.

M.S. "COPELAND."—Twin-screw cargo vessel, with refrigerated space for the carriage of dairy produce, built by The Caledon Shipbuilding and Engineering Company, Limited, Caledon Shipyard, Dundee, for the Belfast-London trade of the Clyde Shipping Company, Limited, 78, Carlton-place, Glasgow, C.5. Main dimensions: 235 ft. by 38 ft. by 18 ft.; gross tonnage, 1,200. Engines of Atlas-Diesel-type, supplied by Messrs. British Polar Engines, Limited, 139, Helen-street, Govan, Glasgow, to give a speed of 13 knots. Launch, December 29.

S.S. "OYO."—Twin-screw pump hopper dredger built by Messrs. Wm. Simons and Company, Limited, London Works, Renfrew, to the order of the Crown Agents for the Colonies, Millbank, London, S.W.1, for the service of the Government of Nigeria at Lagos. Dredging and discharging capacity, 4000 tons of spoil per hour. Triple-expansion engines, with three multitubular boilers arranged for coal burning. Launch, December 30.

M.S. "LOTORIUM."—Single-screw oil tanker built by Messrs. Harland and Wolff, Limited, Queen's Island, Belfast, for Messrs. Anglo-Saxon Petroleum Company, Limited, Great St. Helen's, London, E.C.3. Main dimensions: 446 ft. by 54 ft. 3 in. by 31 ft.; gross tonnage, 6,450. Harland-B. and W. four-cycle six-cylinder Diesel engine. Trial trip January 1.

WILBUR WRIGHT LECTURE.—The 36th Wilbur Wright Memorial Lecture of the Royal Aeronautical Society will be delivered by Mr. A. Gouge, B.Sc., F.R.Ae.S., on May 27. The subject and other particulars will be announced at a later date.

BRITISH STANDARD SPECIFICATIONS.

THE following specifications have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, at the price quoted at the end of each paragraph.

Mixing Valves for Hot and Cold Water.—A new specification, B.S. No. 1415-1947, covering manually-operated mixing valves for ablutionary and domestic purposes, has now been issued. The term "mixing valve" relates to an appliance into which supplies of hot and cold water enter through valve ports, are mixed in a specially formed chamber and are thence delivered through a common outlet, the temperature of the mixed water being governed, through a nominal range, by the manual operation of a single control. The standard is concerned with unifying the size of valves, minimum standards of performance and the provision of certain essential safeguards concerning the method of operation. Three sizes are dealt with, namely, $\frac{1}{2}$ in., $\frac{3}{4}$ in., and 1 in., the size being specified by means of the nominal bore through the inlets, in conjunction with the performance requirements. In all cases the sequence of operations of the valve must comprise the positions: off or shut, cold, warm or tepid, and hot. Performance is defined as the maximum head loss, in feet, for given rates of flow through the fitting for each size of valve. Castings and stampings are to be subjected to a pressure test and the completed valves are to be tested against pressure in the "off" position, and, for performance, by weighing the discharged mixed water flowing through the valve and entering a 30-gallon capacity cistern mounted on a weighing machine. [Price 2*s.*, postage included.]

Malleable-Iron Castings.—Revisions of two specifications, namely, B.S. No. 309, covering whiteheart malleable-iron castings, and B.S. No. 310, covering blackheart malleable iron castings, have recently been published by the Institution. Two grades of whiteheart and three of blackheart iron are covered. In all cases the test requirements include a tensile test and either a bend test or an analysis certificate of the phosphorus content. Provision is also made for additional tests, to be called for where appropriate. In the case of whiteheart castings the provision and heat treatment of test bars are specified and the test requirements are related to three different sizes of test bars selected according to the principal sectional thicknesses of the castings. The provision, heat treatment and dimensions of blackheart malleable test bars are also specified. In both specifications details regarding workmanship and finish, machineability and testing facilities, are included. [Price 2*s.* each, postage included.]

BOOKS RECEIVED.

The British Electrical and Allied Industries Research Association. Technical Report D/T34. *The Elimination of Defective Mica Plates for Capacitors by Visual Inspection.* By A. MORRIS THOMAS. [Price 3*s.* 6*d.* net.] Technical Report G/T185. *Exploratory Tests on Overvoltages Due to Switching Operations on Open Overhead and Composite Transmission Lines.* By L. GOSLAND. [Price 7*s.* 6*d.* net.] Technical Report G/T198. *Fundamental Study of the Performance of Cartridge Fuses in A.C. Circuits.* By H. W. BAXTER. [Price 6*s.* net.] Technical Report M/T90. *Modifications to Reception Set R.206 Mark 1 for the Measurement of Radio Interference.* By S. F. PEARCE, A. TURNEY and D. C. G. SMITH. [Price 13*s.* 6*d.* net.] Technical Report M/T92. *Radio Interference Tests on an Electrified Railway.* By S. F. PEARCE. [Price 1*s.* 6*d.* net.] Technical Report S/T55. *The Effect of Humidity on the Surge Performance of a Transformer.* By K. L. SELIG. [Price 3*s.* 6*d.* net.] Offices of the Association, 15, Savoy-street, Strand, London, W.C.2.

Forty-Second Annual Report of the Rand Water Board for the Financial Year Ended 31st March, 1947. The Secretary, Rand Water Board, Johannesburg.

Ministry of Education. Working Party Reports. National Advisory Council on Education for Industry and Commerce. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 2*d.* net.]

British Columbia Department of Mines. Annual Report of the Minister of Mines for the Year Ended 31st December, 1946. British Columbia Department of Mines, Victoria, B.C.

The Atom and its Energy. By PROFESSOR E. N. DA C. ANDRADE, F.R.S. G. Bell and Sons, Limited, York House, Portugal-street, London, W.C.2. [Price 10*s.* net.]

Summary Report of the Ministry of Works for the Period 9th May, 1945, to 31st December, 1946. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1*s.* net.]

The International Mercantile Diary and Year Book, 1948. The Syren and Shipping Limited, 26-28, Billiter-street, London, E.C.3. [Price 25*s.* net.]

PERSONAL.

SIR ROBERT DALTON, C.M.G., United Kingdom Senior Trade Commissioner in the Commonwealth of Australia and Economic Adviser to the United Kingdom High Commissioner at Canberra, is due to retire on April 5 after 46 years in the public service. He will be succeeded by MR. J. B. GREAVES, O.B.E., at present serving as Counsellor (Commercial) at Washington.

MR. W. W. MACARTHUR, M.I.Mech.E., M.I.P.E., has left the service of the Fairey Aviation Company, Limited, Hayes, Middlesex, to take up the appointment of managing director of Air Ducts Limited, Brentford, Middlesex, the principal subsidiary company of Richard Crittall and Company, Limited. He has also been appointed executive director of Messrs. Richard Crittall's Glasgow factories.

MR. W. L. FRASER, C.M.G., has been elected a director of Tube Investments, Limited, The Adelphi, London, W.C.2, and has been appointed a deputy chairman. SIR EDMUND CRANE has relinquished his position on the board prior to leaving this country for a visit to South Africa.

MR. J. S. KILLICK, C.B.E., M.I.C.E., has been elected an additional director of Messrs. George Wimpey and Company, Limited.

MR. T. P. EVERETT, until recently manager of the land department of the Hartlepool works of Richardsons, Westgarth and Company, Limited, has been appointed a director of the company. MR. B. B. WYATT has been appointed manager of the land department in succession to Mr. Everett. MR. W. E. LOVERIDGE will continue as resident director in charge of the Hartlepool works.

SIR THOMAS BARLOW, G.B.E., has had to relinquish his chairmanship of the Council of Industrial Design, owing to ill health. He is to be succeeded by DR. R. S. EDWARDS, A.R.C.Sc., who has been a member of the Council since its formation in December, 1944.

MR. R. LONG, B.Sc., A.R.I.C., A.M.Inst.Gas E., who is at present on the staff of the Joint Research Committee of the Gas Research Board and the University of Leeds, has been appointed Lecturer on Fuels, Department of Chemical Engineering, University of Birmingham.

MR. LEWIS W. PHILLIPS, M.I.E.E., F.Inst.P., has been appointed technical editor to Messrs. Macdonald and Company (Publishers), Limited, St. Paul's Chambers, 19, Ludgate-hill, London, E.C.4.

MR. R. B. PULLIN has relinquished the position of managing director of Messrs. R. B. Pullin and Company, Limited, but remains chairman. MR. P. J. ELLIS has resigned his position of general manager to become managing director. MR. A. G. FRAZER-NASH continues as a director; MR. B. T. DYETT is elected an additional director and remains secretary.

MR. A. C. CROCKATT, A.M.I.Mech.E., has been elected a director of Messrs. William Crockatt and Sons, Limited, Simplex Works, 64, Darnley-street, Glasgow, S.1.

MR. FRANK DANIELS, for many years head of the Dagenham tractor department of the Ford Motor Company, Limited, has been appointed sales manager, tractors and agricultural machinery.

MR. A. E. REIF, B.A., B.Sc., Scientific Officer, The British Coke Research Association, has been awarded the Institute of Fuel's Students' Medal and Prize for 1947 for his paper on "Lump Density of Coal."

MR. R. K. BACON, Director of the Overseas Information Branch, Board of Trade, has been appointed deputy head of the Economic Information Unit.

The London headquarters of the TIMBER CONTROL have been moved from No. 7 to No. 30, Cadogan-square, London, S.W.1. (Telephone: KENsington 5131). The telephone number of the Birmingham (No. 13) area office has been altered to Bearwood 2301.

THE BRITISH ALUMINIUM COMPANY, LIMITED, Salisbury House, London Wall, E.C.2, announce that their Midland warehouse at 17-18, Providence-street, Cradley Heath, Staffordshire. (Telephone: Cradley Heath 6881), is now in full operation. The company's Midland Branch office remains at Lansdowne House, 41, Water-street, Birmingham, 3.

The head office of the ASSOCIATION OF SUPERVISORY STAFFS, EXECUTIVES AND TECHNICIANS, is now at 110, Park-street, London, W.1. (Telephone: MAYfair 8541-2).

MESSRS. WILD-BARFIELD ELECTRIC FURNACES, LIMITED, Elecfurn Works, Watford By-Pass, Watford, Herts., announce the formation of INDIAN WILD-BARFIELD COMPANY, LIMITED, with offices at Fort Chambers, 6-10, Dean-lane, Hammam-street, Fort, Bombay, and under the local management of MR. R. A. P. MISRA. The new company have also been appointed sole distributors and agents for the products of MESSRS. G.W.B. ELECTRIC FURNACES, LIMITED.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel.—During the New Year holiday of about ten days, squads of workmen were engaged at the steelworks overhauling machinery and rebuilding or repairing furnaces, preparatory to another long run. Success will depend largely, however, on raw material supplies. Heavy throughputs in the last four months of 1947 exhausted scrap reserves, and at the outset, at least, makers will be dependent on day-to-day deliveries of metal for furnace charges. Production in 1948 has seen the start of an additional blast-furnace in Scotland. Following repairs to a furnace damaged by an explosion at Govan Ironworks on December 10, a reserve unit has also been brought into commission. It is not yet clear whether both furnaces are to continue in operation. There are suggestions that the new blast-furnace at Clyde Ironworks, belonging to Messrs. Colvilles, Limited, is to start up some time this month. An intensification of scrap collection has been taking place following the general appeal by the Steel Board for increased salvage. Steelmakers have been disturbed at the effect which the increased use of pig-iron would have on the selling prices of steel and steel products, and are awaiting the results of scrap collection with some anxiety. Local consumers of steel products have heavy order books for years ahead, and are hoping that steelmakers will be able to shorten delivery dates in 1948. The steel industry is confident that given the assurance of raw material supplies, it will maintain an ingot tonnage over a period equivalent to an annual rate of 2,000,000 tons.

Scottish Coal.—The pits finished up for 1947 on a very strong note on Tuesday, December 30. In the preceding week, when all collieries were due to work the full six days, production amounted to 521,000 tons (provisional), the highest weekly total for the year. Compared with the previous week's figure of 508,000 tons, the next best for 1947, the record week was below expectation, owing to absenteeism of as high an order as 15 per cent. in some areas. During the year, production, provisionally, was 22,964,600 tons. This was about 299,000 tons higher than in 1946, but was short of the 1937 output by over 9,000,000 tons. The Divisional Production Director has set the 1948 target at 25,000,000 tons, but stated at the time that it was hoped that 26,000,000 tons would be obtained. Assisted by better weather in the second half of 1947, opencast production was also higher than in the previous year. Final figures are expected soon, but by the end of November, the production had already exceeded the total of 584,600 tons for the whole of 1946 by some 53,200 tons. Satisfactory holiday tonnages were provided for continuous-process undertakings and power-supply companies, while good stocks were held by other classes of consumer for the general resumption by industry. Extra railway tonnages were supplemented by over 2,000 tons of briquettes from South Wales. Domestic supplies were affected by the general shortage of large coal, but deliveries on the two final production days were improving. Parcels have been released periodically for shipment to Eire, Sweden, Denmark, Portugal and France, and exporters are expecting a rapid expansion in allocations in the new future.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The overhaul and repair of plant and machinery at the steelworks during the holiday period was hampered by a scarcity of electrodes. There was a fairly satisfactory return to work after the holidays, and progress is being made with dealing with numerous orders on the books. Manufacturers are concerned about the recurrent rises in prices of coal and the consequent increases in the prices of coke, gas and electricity. They fear that it will make it extremely difficult to meet competition from Continental makers of steel and tools. Sheffield firms are already facing competition from Czechoslovakia and Austria, and they predict that this will become intensified when German industry recovers. Special steps are being taken to accelerate the production of coal-mining machinery and equipment, improved types of which have been on order for some time, some machinery being of American types both for deep-mining and open-cast working. Railway-material departments are very actively employed, but report a continued shortage of steel, to remedy which additional furnaces are to be brought into operation.

South Yorkshire Coal Trade.—At some pits there was an attendance of only about 60 per cent. on New Year's day, but since then absenteeism has been reduced to about the usual proportions. Industrial users have made some small additions to their reserves, and the railways have been trying to replenish the stocks depleted during the Christmas period. Scarcity of coke is one of the difficulties, but there has been promise of fuller allocations of coking coal. Opencast working has been interrupted by bad weather, but the position is improving. House coal of better quality than that previously available has been allocated to retail merchants.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—Important steps towards the re-organisation of the South Wales mining industry were foreshadowed in a New Year message issued by the executive council of the South Wales area of the National Union of Mineworkers. It was announced that a joint statement on the matter would be issued shortly by the union and the divisional coal board. A development of considerable interest on the steam-coal market during the past week has been the completion of arrangements to send a cargo of 2,400 tons of bituminous coal to France. The news was taken to mean the resumption of ordinary trade with France, which was the chief customer of South Wales in pre-war years. It was recognised that shipments for some time must remain on a restricted scale. The Director-General, in Great Britain, of the French coal-buying organisation visited Cardiff in the week to discuss future policy. Business was also arranged for a cargo of 6,500 tons of bunker coals for delivery to Montevideo, this being the first to be delivered to Uruguay for a long time. Other business was reported to be under negotiation for Portugal and South America. There has been no reduction in the inquiries from inland customers on the steam-coal market, and all the top-grade coals were in very short supply for delivery during the next month or so. High-priority consumers were making heavy demands, and as there is no sign of this declining the amount of coal available for shipment abroad was limited, although it was expected that the shortage of railway wagons would result in some shipments being made for the sole purpose of getting a quick return of empties. The demand for bunker classes was active for delivery at the local ports and the principal coaling depots, and in this connection it was reported that business had been completed for Freetown and Port Said. Cokes and patent fuel were only sparingly available for delivery over a long time ahead.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The aggregate tonnage output of iron and steel is maintained at a very high level, but the large distributable tonnage still falls greatly below customers' present needs. Buyers are still anxious to place new orders for delivery over any period permitted by existing conditions. The recognised market values attract little or no attention, both home and overseas customers readily agreeing to pay the fixed prices ruling at time of delivery. The recent achievements of iron and steel producers encourage the belief that the industry is capable of exceeding the output target for 1948, providing adequate supplies of various descriptions of raw materials and semi-finished and finished commodities are obtainable. The output of Cleveland ironstone is still less than the demand, but a considerable expansion in output is likely in the near future. Meanwhile moderate parcels from mines in other home iron centres are reaching Tees-side, and imports of high-grade foreign ore remain on a satisfactory level. Much larger production and greater distribution of pig iron is urgently needed for home requirements; the scarcity, coupled with the acute shortage of scrap for the foundries and steel furnaces, continues to check operations at works turning out much-needed commodities.

Foundry and Basic Iron.—Users of ordinary foundry pig, especially, are complaining of inadequate supplies. Better deliveries are promised, but consumers fear that the increase of make in the near future will be insufficient. The production of the basic-iron furnaces is rapidly taken up for local consumption and there is a persistent demand for larger supplies.

Hematite, Low-Phosphorus and Refined Iron.—Manufacturers of East-Coast hematite are able to keep pace with the current requirements of their regular customers, but are unable to cope with the demand for deliveries to enable stocks to be built up. The output of low- and medium-phosphorus grades of iron are barely sufficient to cover the consumers' actual needs. Refined-iron firms have a ready sale for their products.

Manufactured Iron and Steel.—Makers of semi-finished and finished iron have substantial bookings, and steel producers have very heavy commitments. A further improvement in the output of steel semies is most welcome, but the rather better supply is still short of the demand for the re-rolling mills. Any usable defective crops are promptly taken up. Parcels from overseas are few and small. Expansion in the production of several descriptions of finished material would be followed quickly by an appreciable further increase in the supplies of sheet bars and billets. Ingot production, however, is at a very high level and large quantities are reaching the heavy rolling mills. Colliery equipment is still in very heavy demand and there is no abatement in the demand for shipbuilding material, black and galvanised sheets, and railway requirements.

NOTICES OF MEETINGS.

It is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

JUNIOR INSTITUTION OF ENGINEERS.—*North-Western Section:* Monday, January 12, 7 p.m., 16, St. Mary's Parsonage, Manchester. "Production of Alternating-Current Circuits," by Mr. H. H. Daniels. *Institution:* Friday, January 16, 6.30 p.m., 39, Victoria-street, S.W.1. Symposium on "Railways."

INSTITUTION OF PRODUCTION ENGINEERS.—*Halifax Section:* Monday, January 12, 7 p.m., White Swan Hotel, Halifax. "Britain's Industrial Future," by Mr. Lewis C. Ord. *Luton Section:* Monday, January 12, 7 p.m., Town Hall, Luton. "Press Work," by Mr. A. Grainger.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Sheffield Branch:* Monday, January 12, 7.30 p.m., Royal Victoria Hotel, Sheffield. "Use of Fulbond in Foundries," by Mr. L. Roy. *W.R. Yorkshire Branch:* Tuesday, January 13, 7 p.m., University, Leeds. "Amenities in Foundries," by Mr. H. Berry. *Middlesbrough Branch:* Friday, January 16, Cleveland Scientific Institute, Middlesbrough. Film: "High-Quality Steel," presented by Mr. W. H. Salmon.

INSTITUTION OF ELECTRICAL ENGINEERS.—*North-Eastern Centre:* Monday, January 12, 6.15 p.m., Neville Hall, Newcastle-upon-Tyne. "Gas, Electricity and Coal Economy," by Mr. P. Schiller. *London Students:* Monday, January 12, 7 p.m., Victoria-embankment, W.C.2. "The Engineer in the Post-War World," by Sir Arthur Fleming. *East Midland Centre:* Tuesday, January 13, 6.30 p.m., Electricity Showrooms, Derby. "Oil Deterioration in Transformers and Switchgear," by Mr. H. Hurworth. *Radio Section:* Wednesday, January 14, 5.30 p.m., Victoria-embankment, W.C.2. "Reference-Crystal-Controlled V.H.F. Equipments," by Messrs. D. M. Heller and L. C. Stenning. *Scottish Centre:* Wednesday, January 14, 6 p.m., Heriot-Watt College, Edinburgh. "Teaching Principles of Electrical Machine Design," by Mr. L. H. A. Carr. *Institution:* Thursday, January 15, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. "Standardisation of Switchgear," by Messrs. D. E. Lambert and J. Christie. *Measurements Section:* Friday, January 16, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. "Survey of Metering Practice on the British Grid System," by Mr. F. Byrne.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, January 13, 5.30 p.m., Great George-street, S.W.1. Film: "Swedish Bridge Construction and the Sando Bridge," introduced by Mr. Sven Klingerg.

INSTITUTE OF MARINE ENGINEERS.—Tuesday, January 13, 5.30 p.m., 85, Minories, E.C.3. "Sea Water Contamination of Boiler Fuel Oil," by Engr. Capt. C. J. Gray and Mr. Wycliffe Kilner.

ILLUMINATING ENGINEERING SOCIETY.—Tuesday, January 13, 6 p.m., 2, Savoy-hill, W.C.2. "Modern Flash Discharge Tubes," by Mr. C. R. Bicknell.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, January 13, 6.30 p.m., 39, Elmbank-crescent, Glasgow. "Radar for Marine Navigation," by Mr. A. K. Nuttall.

NEWCOMEN SOCIETY.—Wednesday, January 14, 5.30 p.m., Science Museum, S.W.7. "Sir John Barton's Iris Ornaments," by Mr. P. Grodzinski.

INSTITUTE OF PETROLEUM.—Wednesday, January 14, 5.30 p.m., 26, Portland-place, W.1. "Structure and Properties of Ethylene Polymers," by Mr. R. B. Richards.

INSTITUTION OF LOCOMOTIVE ENGINEERS.—Wednesday, January 14, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, S.W.1. "Southern Railway All-Steel Suburban Electric Stock," by Messrs. L. Lynes and C. A. Shepherd.

INSTITUTION OF MINING ENGINEERS.—Thursday, January 15, 11 a.m., Institution of Civil Engineers, Great George-street, S.W.1. Annual Meeting. Presidential Address by Professor J. A. S. Ritson. "Geological Aspects of Coalfields," by Mr. J. K. Allan.

DIESEL ENGINE USERS ASSOCIATION.—Thursday, January 15, 2.30 p.m., Caxton Hall, Victoria-street, S.W.1. "Porous Chrome-Hardening of Diesel-Engine Cylinders," by Mr. C. D. B. Williams.

INSTITUTION OF MINING AND METALLURGY.—Thursday, January 15, 5 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Mechanisation of Iron Ore Mining," by Mr. W. E. Davies.

ROYAL AERONAUTICAL SOCIETY.—Thursday, January 15, 6 p.m., Institution of Civil Engineers, Great George-street, S.W.1. "Gas Turbine Accessory Systems," by Mr. O. N. Lawrence.

INSTITUTION OF MECHANICAL ENGINEERS.—Friday, January 16, 5.30 p.m., Storey's-gate, S.W.1. Film: "The Screen in Relation to Engineering Training," introduced by Mr. H. R. Hockley.

TEMPERATURE OF RAILWAY BRAKE BLOCKS.

(*For Description, see Page* 45.)

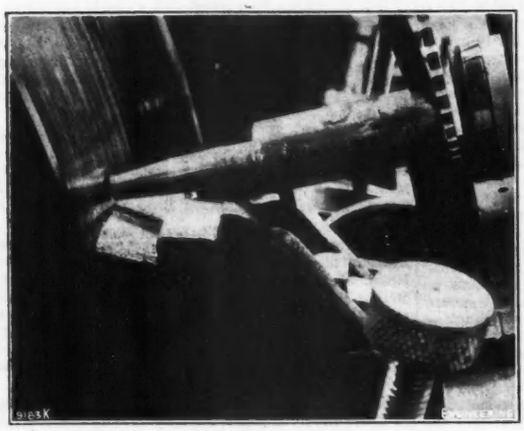


FIG. 8. COPPER SIGHTING TUBE AND TYRE.

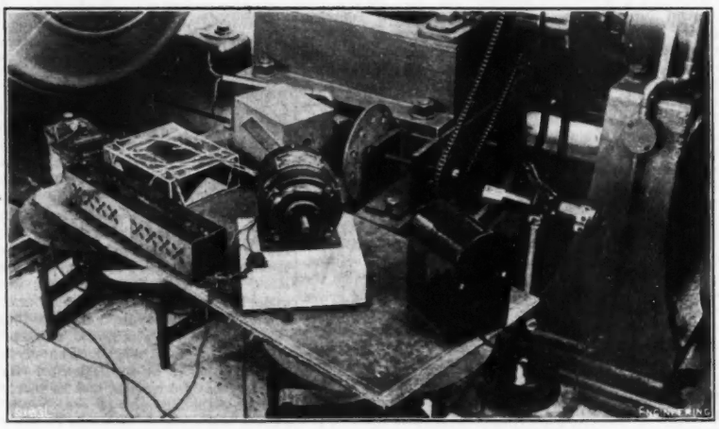


FIG. 9. DECELERATION AND TIME-MARKING UNIT.

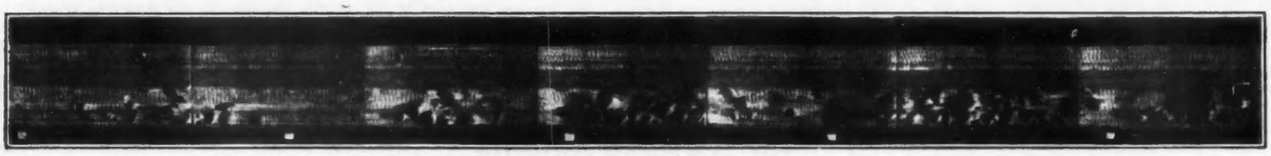


FIG. 10. PANORAMIC VIEW OF HALF-CIRCUMFERENCE OF TYRE.

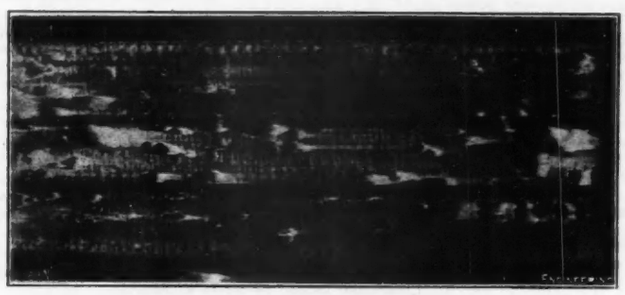


FIG. 11.

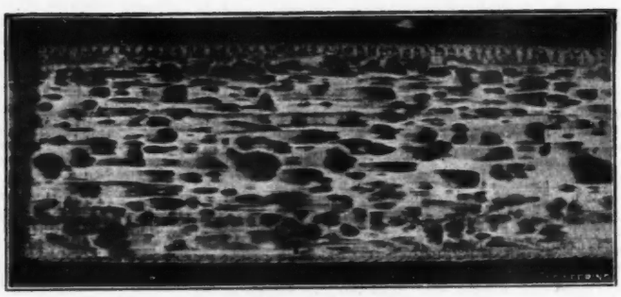


FIG. 12.

FIGS. 11 AND 12. HEAT SPOTS AT EXTREMITIES OF DIAMETER.

FIG. 13. DISTRIBUTION OF HEAT SPOTS ACROSS TREAD.

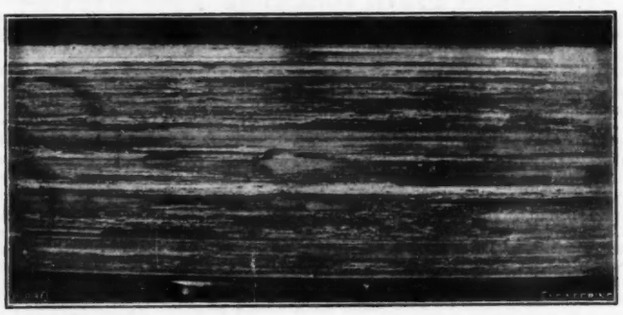


FIG. 14. DAMAGE CAUSED TO TYRE BY CAST-IRON BLOCKS.

MOVIEGRAM SONO-VISION UNIT.—Details of a self-contained unit for showing sound or silent films in daylight, for educational and publicity purposes, have been sent to us by Messrs. Moviegram (Equipments), Limited, 3, Albemarle-street, Piccadilly, London, W.1. A brief reference to it was made on page 561 of our previous volume, but we regret that it was wrongly described as a film-strip projector. The unit is in the form of a cabinet, 6 ft. 4 in. high, mounted on castors, with a translucent screen 2 ft. 5 in. by 1 ft. 9 in., and also containing the projector, speaker, amplifier, film reels and controls. The unit takes 16-mm. films and is very convenient in use. A film may be started or stopped, as required, or be set for continuous repetition, without the necessity for rewinding. A microphone may be attached, if it is desired to give a commentary; the unit is suitable for an audience of up to 200 people. The film is projected on to the screen from the rear, inside the cabinet, which enables the unit to be used in daylight.

SCHOLARSHIP AWARDS IN NAVAL ARCHITECTURE AND MARINE ENGINEERING.—The Council of the Institution of Naval Architects, 10, Upper Belgrave-street, London, S.W.1, have announced the award of the 1851 Exhibition Commissioners Post Graduate Research Scholarship in Naval Architecture for 1947 to Mr. J. F. Leathard, of King's College, Newcastle-upon-Tyne. It is tenable for two years, and has an annual value of 500*l*. The Vickers-Armstrongs Scholarship in Naval Architecture has been awarded to Mr. John L. Gaunt, of Messrs. William Denny and Brothers, Limited, Dumbarton. The scholarship is of the value of 200*l*. per annum and will be held at Glasgow University for four years. The Denny Scholarship in Naval Architecture, of the annual value of 130*l*., tenable at Glasgow University for four years, has been awarded to Mr. J. S. Shand, of Dumbarton Academy. The Yarrow Scholarship in Marine Engineering has been awarded to Mr. L. R. Prew, of H.M. Dockyard, Devonport. The scholarship is of the value of 175*l*. per annum and will be held at King's College, Newcastle-upon-Tyne, for three years.

ENGINEERING.

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The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years

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ENGINEERING

FRIDAY, JANUARY 9, 1948.

VOL. 165. No. 4276.

STRESS ANALYSIS BY FREEZING.

THE transmission of light from one medium to another has been a problem for investigation by the student of natural philosophy throughout the ages; dioptrics and refraction are discussed in the fifth book of Ptolemy's *Optics*. Jean de Meung, author of the Thirteenth-Century *Romance of the Rose*, leaves no doubt as to his approval of Ptolemy's theory when, in referring to rainbows, he remarks that

> "Only he who's learned the rule
> Of optics in some famous school
> Can to his fellow men explain
> How 'tis that from the sun they gain
> Their glorious hues."

For engineers in these days, special importance attaches to the phenomenon of refraction since the discovery by Sir David Brewster, in 1816, that, when a specimen of glass is subjected to stress by loading and is viewed in polarised light under suitable conditions, it exhibits brilliant colour effects because the glass has changed its optical properties and thus has become doubly refracting. Brewster suggested, therefore, exploring the distribution of stress in masonry arches by means of glass models, and this was followed up, many years later, by Augustin Mesnager in Paris and by the late Professor E. G. Coker, who eventually devised apparatus for use with any system of static loading and any structural component which can be represented by a plate model of transparent material stressed in its own plane. To this extension of the method the late Professor L. N. G. Filon contributed much in the way of essential theory. During the past decade or so, important advances on the experimental side have been made in England, the United States, and in other countries, as was pointed out by Mr. W. A. P. Fisher and Mr. R. B. Heywood in the papers which they read before the Institution of Mechanical Engineers on December 12, 1947, as recorded in our issue of December 19.

These papers, taken together, present a fairly complete survey of the subject, including the application of the "stress-freezing" method to problems of three-dimensional stress. In this method, use is made of the fact that certain synthetic resins of the thermo-setting type possess considerable thermo-plasticity, so that, when heated to a particular temperature, they become "rubbery" and deform quite easily under small loads. Further, on cooling under load, such resins set again, but in a strained condition, and retain both the strain and the photo-elastic effect developed, while in the softened state, even when the load is removed. In this manner, the stress may be fixed or "frozen" in one of several transparent materials which, in the softened state, are characterised by two remarkable properties. First, in the thermo-plastic condition, they obey Hooke's law very accurately, though their Young's modulus is only about 1/120 of the value at room temperature. Second, there is the fact that careful machining or cutting of these substances does not materially affect the photo-elastic pattern. This enables the investigator to slice through a solid model and thus to obtain a picture of the system of stresses in any desired plane. To explain the persistence of the frozen-stress pattern despite cutting, it is necessary to suppose that the interaction of the two components of the substance, one partly elastic and the other partly viscous at room temperature, is completely balanced for every particle of the material separately. Thus the frozen-stress system is quite different from the "locked up" stresses, such as occur in hardening, where the removal of material generally relieves the stress. In the transparent materials used for the purposes of this work are included a condensation product of glycerine and phthalic acid known as Glyptal resin or Bakelite B.T. 61893, and a glass-clear phenol-formaldehyde resin known as Catalin 800; the former cannot be obtained in thicknesses exceeding 1 in., but the latter, which gives a higher stress-optical coefficient, can be obtained in larger sizes.

The practical value and scope of the freezing method depends not only on the development of suitable apparatus, but also on an adequate supply of resins having the physical properties required to obviate spurious effects, such as the "time-edge stress," which may arise from the development of stress at the edge of a model due to the absorption or loss of moisture. The matter of absorption is of importance also in the process of heating the model, since loss of moisture and other volatile constituents may occur at the surface, with the result that the outer skin, or rind, tends to contract, but is prevented from doing so by the resistance of the inner material. The effect of this is tension at the boundary, with a corresponding compression, more diffused, farther inside; and, to minimise this "rind effect," the time of heating should be as short as possible. Again, some of the resins found suitable for this method exhibit both mechanical and optical creep at room temperature. In addition, the material must possess such physical properties as homogeneity, isotropy, high transparency, freedom from initial stress, machinability, and low creep. These factors naturally influence the technique in different ways; for instance, the strain in the softened condition may be so great as appreciably to affect the shape of the model unless the stress is limited to a certain value. Thus the specification calls for a sufficiently small fringe value, when soft, to produce an adequate fringe pattern without excessive strain; a requirement which is by no means easy to meet, since the strains allowed in this work are of the order of ten times the total strain developed in the metal prototype at 0·1 per cent. proof stress.

In these circumstances, students of the subject will welcome the comparison of the properties of Catalin and Glyptal which is given in the paper by Mr. Fisher, for, in the case of Catalin, the point has nearly been reached where the weight of the model itself may produce sensible stress. Comparison of the strains, for the same fringe order in the same material, shows that the strain in Glyptal is about 22 times as great in the softened condition as at room temperature, while for Catalin the ratio is about four. At room temperature, the Glyptal resin, because of its low strain/fringe figure and relatively high elastic limit of about 5,500 lb. per square inch, permits quite high fringe orders within the elastic range, with strains sufficiently low to preserve the shape of the model. This advantage, however, is lost at the softening temperature, when the strain in Glyptal is twice as great as that for Catalin, with the same fringe order in each case.

It would be a step forward, therefore, if a material could be found which gave the same birefringence for a still lower strain, when softened, coupled with satisfactory freezing characteristics. The comparative merits of these resins depends also on the process of "curing." Experience shows that a phenol-formaldehyde resin such as Catalin 800 softens readily at a temperature of 176 deg. F. and produces good frozen patterns, but there is a small "after creep," resulting in a reduction of fringe order by about 6 per cent. in 200 hours. In the case of Glyptal resin, the softening temperature is higher, the creep at room temperature is very slight, and the material has a high rigidity. Improvement of the available materials and discovery of new ones are evidently matters for consideration by a chemist acquainted with the effect of cross-linking in the long-chain molecules of such resins.

Existing methods and materials, however, afford a useful means of exploring the distribution of stress in three-dimensional problems. Two interesting applications were mentioned by Mr. Heywood. To examine the stress concentrations produced by the action of the gas load on the seat of a high-duty poppet valve, a Bakelite model was mounted in apparatus in which the uniform gas pressure on the combustion face was applied by means of a column of mercury. The whole apparatus was then placed in an oven specially-designed for this work, there subjected for two hours to a temperature of 230 deg. F., and then allowed to cool at a uniform rate for six hours. After the stresses in the Bakelite model were thus frozen, slices ⅛ in. in thickness were cut parallel to its axis. In this instance, the stress distribution over the entire surface of the valve head was given by the fringe pattern of a single slice, since the stresses were symmetrically disposed about the axis of the valve and the directions of the principal stresses were radial and circumferential. As a result of these model tests, the stresses were reduced by redistributing the material of the valve. In the other case, a crankshaft was examined for stress and distortion by using the freezing method of analysis, and several interesting facts were brought to light by tests with a model. It was found that the gas loading of the crankshaft brought about stresses similar to those produced by a simple torque applied to the crankshaft, but the torque stresses were in general greater, hence it was considered advisable to carry out the tests under torque conditions. After freezing with a torque applied to the model, it was discovered that the webs had twisted, and therefore required stiffening. Moreover, the lightening hole in the crankpin had distorted to an ellipse with an inclined axis, and several concentrations of stress had occurred in weak parts of the crankshaft.

Of equal interest is the scope of the method for investigating the internal stresses associated with rapid quenching of machine parts. On this point, experiment shows that, if a model of Bakelite is held at a temperature of about 212 deg. F. and then plunged into cold water, the resulting internal stresses in the material can be measured by means of the fringes. On slicing the model the investigator may explore the distribution of stresses which are known to represent the true residual stresses, and not the freezing stresses. From inspection of a series of such slices, it should be possible to estimate the stress condition of the model before it was cut. Although it does not seem likely that quantitative results can be ascertained, because of the number of properties involved in quenching, the procedure should yield a fairly accurate indication of the distribution of stress over the model. This aspect of the matter merits further research, for the measurement of internal stress is by no means simple, whether by the present method or by measurement of the distortion upon removal of the internal stress by cutting the part or by the X-ray back-reflection method. Such stresses are of practical importance because their magnitude may be greater than those produced by the external load. The fact that the freezing method is open to criticism as regards accuracy, cost and a more simplified technique should stimulate effort on the part of those concerned with progress in this field, chemists as well as engineers, to find solutions to the outstanding problems which only their combined efforts and skill can solve.

THE PHYSICS OF ARC WELDING.

IT has sometimes been said that the high efficiency of many types of electrical machine may be attributed to the fact that the theoretical basis on which they operate is well understood and that their performance and various losses lend themselves to precise measurement. Although outputs of mechanical prime movers and other appliances may be accurately determined, the sorting out of the various influences which affect their efficiency is difficult and sometimes impossible, so that the improvement on earlier days which has now been achieved is mainly based on *ad hoc* experiment, which, however, has been supported by much theoretical reasoning. An exception to the superiority, or advantage, of electrical methods in this matter of accurate and selective measurement appears to be furnished by arc welding, as "the physical and chemical terms which define the requirements of a satisfactory weld are, to a large extent, unknown." Arc welding has now established a firm position both as a workshop method and for use in the field, but, despite much theoretical and experimental work, its development appears to have been essentially empirical. It is hardly too much to say that the definition of a good welding method is one that produces a good weld.

This point of view is sustained by a recent technical report,* published by the British Electrical and Allied Industries Research Association, from which the quotation in the preceding paragraph has been taken. The report has been prepared in co-operation with the British Welding Research Association. Its contents give an indication of the large amount of experimental work which has been devoted to the problems of arc welding, but are not able to record any generally-accepted opinions about the physical basis of the process. But little consideration is necessary for a realisation of the practical difficulties attached to experimental investigation of the matter, particularly in view of the fact that any instrumental procedures which may be adopted for the purposes of observation and measurement may, in themselves, alter the quality of the phenomenon under investigation.

It is clear that the basic factor in arc welding must be the arc, but "little of a fundamental nature is known about the electric arc at atmospheric pressure." As the report is concerned with electric welding as a practical process it does not enter into a consideration of the various theories of the physics of the arc *per se* which have been advanced. Its subject is the summarising of available information on the phenomena peculiar to welding arcs, and its object is to draw attention to the more important fields in which further research is desirable. As is pointed out, the conditions under which successful arc welding may be carried out cover a wide field. It may be applied in the downward, horizontal, vertical and overhead positions; it may be carried out with bare, dipped, lightly coated and heavily coated electrodes; direct current of either polarity or alternating current may be employed; and it may be utilised with a variety of ferrous and non-ferrous metals. These very varied conditions cannot necessarily be combined at random, but all are aspects of some sphere of practice, and although there must be some fundamental factors basic to the welding process, they have, so far, not been traced amid the widely varied types of procedure which are possible. The report states that "there appears to be no one criterion which must be satisfied in all welds." Might it be suggested that the true position is that that criterion has not yet been discovered?

The report is divided into three sections dealing, respectively, with "Transfer of Material in Welding Arcs," "Temperature of Welding Arcs," and "Stability of Welding Arcs." The first of these is concerned with the practical aim of electric welding; the others are incidental conditions of the process. The review of the literature of the subject which is presented appears to establish that some 90 per cent. of the transferred metal crosses from the welding rod to the weld in a liquid state and about 10 per cent. as condensation and vapour. Experiment indicates that material traverses the gap either as large globules falling under gravity, as smaller globules projected from the electrode tip, or as a shower of fine particles or droplets with appreciable velocity. In the first case, a comparatively large quantity of the electrode is melted and the hanging drop is separated from the welding rod every few seconds under the combined action of gravity, the pinch effect and the general turbulence of the arc stream. This type of action usually takes place in an inert atmosphere. Although gravity may be of some effect when large globules are formed, it is clearly not a fundamental factor in transference, since overhead welding is possible. In diatomic gases, the particles are smaller and leave the electrode at the rate of 10 to 20 per second, but the method by which they are propelled is not fully understood. When the welding arc is short, these processes are modified; the molten metal short-circuits the arc and is severed by the pinch effect and drawn into the weld pool by surface tension. The fine shower of particles moving with appreciable velocity is associated with the presence of oxygen or special electrode coatings.

In view of the wide variations of practice the function and action of electrode coverings is of interest and importance. The conclusions of one investigator, which are quoted, are that the purposes of the coverings are to dissolve impurities in the plate and thus act as fluxes; to change the surface tension of the molten metal and thus make the flow more uniform; and increase arc stability by introducing materials which are easily ionised in the arc stream. These effects occur with lightly-coated electrodes. With a heavy covering, additional actions occur. A reducing or non-oxidising atmosphere is produced around the arc, preventing contamination of the metal in the arc by oxygen and nitrogen in the air; a layer of slag is provided to protect the molten metal in the weld pool; the cup provided around the end of the electrode concentrates and directs the arc; metal may be introduced to alloy with the weld metal; and the sides of the electrode are insulated so that the arc is concentrated at the tip, this action being of importance when welding in a deep V groove. Among the comments made on these conclusions, in the report, are that the term "non-oxidising" can hardly be applied to gases evolved from a cellulose coating since, at the arc temperatures existing, most of the gas will be dissociated; and further, that oxygen is required for crater formation, which occurs when welding with a heavily-coated rod. The arc, however, behaves similarly to one in an atmosphere of carbon monoxide and hydrogen and the reactions are such that, during the cooling of the molten metal, less oxides and nitrides are finally formed than in the case of the bare rod in air.

In connection with the questions of temperature and stability, it is stated that "other things being equal . . . the stability is dependent on the arc temperature," and that "probably part of the arc stabilising produced by electrode coatings is due to the addition of elements of low ionising patented to the arc column, thereby reducing its temperature." The measurement of the arc temperature has been carried out by various methods, which include the introduction of a probe into the electric discharge and measurement of the electron current flowing to it; estimation from gas-density measurements, involving knowledge of the composition of the arc gases, which is usually not available; a sound-velocity method in which a high-intensity sound wave is passed through the arc; and pyrometric measurements. Stability in practical welding means that the arc is easy to maintain in spite of continual change in physical conditions. "Other things being equal . . . stability is dependent on the arc temperature . . . high temperature welding arcs tend to be unstable." As the arc is subject to rapid fluctuations, it is suggested that further work is desirable directed to a rapid, and preferably direct, method of measuring temperature, which is probably the fundamental factor in stability.

* Technical Report, Reference Z/T61. *The Transfer of Material, Temperature and Stability in the Electric Welding Arc. A Résumé of Published Information.* The British Electrical and Allied Industries Research Association, 15, Savoy-street, London, W.C.2. [Price 7s. 6d. net.]

NOTES.

THE HONOURS LIST.

ON page 15, *ante*, we mentioned the names of some of the well-known engineers and scientists included in the New Year Honours List published on January 1. The name of Mr. N. F. Frome, C.I.E., D.F.C., M.I.E.E., chief engineer, Posts and Telegraphs, India, should have been included in the list given of Knights Bachelor. Among the new Knights Commanders of the Order of the British Empire are Rear-Admiral (E) J. L. Bedale, C.B., and Sir Frank Spencer Spriggs, managing director, Hawker Siddeley Aircraft Company, Limited. Mr. G. M. McNaughton, M.I.C.E., M.I.Mech.E., Chief Engineer, Ministry of Health has been created a C.B., Lt.-Col. C. H. Brazel, M.C., M.I.E.E., chief engineer and manager, Department of Government Electrical Undertakings, Ceylon, has been created a C.M.G., Mr. T. A. W. Foy, C.I.E., Indian Service of Engineers, Chief Engineer and Secretary to the Government of the Punjab in the Irrigation Department, a Companion of the Order of the Star of India, and Mr. G. M. McKelvie, O.B.E., Indian Service of Engineers, Consulting Engineer (Roads) to the Government of India, a C.I.E. The honour of Commander of the Order of the British Empire has been conferred upon Mr. G. L. H. Brough, M.I.E.E., Deputy Director of Electrical Engineering, Admiralty; Rear-Admiral (E) G. H. H. Brown, M.I.Mech.E.; Mr. E. G. Clark, M.C., M.I.C.E., secretary, Institution of Civil Engineers; Mr. W. J. Dawson, lately metallurgical director, Hadfields Limited, Sheffield; Major F. B. Halford, F.R.Ae.S., chief engineer and director, de Havilland Engine Company, Limited, Edgware; Mr. W. H. C. Kelland, Chief Engineer, Bengal Nagpur Railway, Calcutta; Dr. W. Kerr, M.I.Mech.E., Emeritus Professor of Civil and Mechanical Engineering and Applied Mechanics, Royal Technical College, Glasgow; Mr. F. A. King, joint managing director, Kelvin and Hughes, Limited; Major A. A. Ross, O.B.E., chief technical adviser to the Director of Engine Research and Development, Ministry of Supply; Mr. T. M. Service, director, William Beardmore and Company, Limited, Glasgow; Mr. R. Starkey, M.Inst.M.M., for public services in Southern Rhodesia; Mr. N. Thornton, M.I.E.E., Chief Engineer and Secretary to the Government of the Punjab in the Public Works Department, Electricity Branch; and Mr. J. P. Watson, special director and manager, Fire Control Drawing Office, Vickers-Armstrongs Limited, Crayford. Among the new Officers of the Order of the British Empire are Mr. C. T. S. Arnett, M.I.E.E., manager, North West England and North Wales Area, Central Electricity Board; Mr. W. J. Berry, M.B.E., A.M.I.C.E., Superintending Engineer, Health Services, Delhi; Mr. S. A. Brazier, technical manager, Dunlop Rubber Company, Limited; Mr. W. C. Crawford, engineer manager, Harland and Wolff Limited, Glasgow; Mr. W. E. Doran, M.I.C.E., chief engineer, River Great Ouse Catchment Board; Mr. J. T. Evans, managing director and engineer, Trent Navigation Company; Captain G. E. T. Eyston, M.C., member of the Southern Regional Board for Industry; Mr. T. A. Guest, mechanical engineer, Manchester Ship Canal Company; Mr. C. Jackson, M.I.Struct.E., Chief Materials Officer, Ministry of Works; Mr. J. P. Jeffcock, M.I.E.E., Deputy Director-General, Civil Aviation, Government of India; Mr. E. G. Phillips, M.I.Mech.E., M.I.E.E., chairman, North Midland Regional Fuel Efficiency Committee; Mr. W. G. Poole, works manager, W. H. Allen, Sons and Company, Limited, Bedford; and Mr. F. A. Ruddock, Assoc. Met., A.R.I.C., Professor of Chemistry and Metallurgy, Royal Naval College, Greenwich. Membership of the Order of the British Empire has been conferred upon Mr. S. J. Eardley, A.M.I.Mech.E., Regional Fuel Engineer, North Eastern Region; Dr. G. H. Forsyth, M.I.Mar.E., M.I.Mech.E., principal engineer surveyor for research, Lloyd's Register of Shipping; Mr. A. J. Ryan, M.I.E.E., A.M.I.Mech.E., lately chief electrical and mechanical engineer, Hastings; Mr. W. J. Stone, A.M.I.C.E., Burma Railways; and Mr. R. R. Whyte, A.M.I.Mech.E., Gas Turbine Department, Metropolitan-Vickers Electrical Company, Limited.

CUTTING TOOLS AND MACHINE TOOLS.

A paper on "Modern Cutting Tools and Machine Tool Design," was presented before the Institution of Mechanical Engineers by Mr. C. Eatough, B.Sc. Tech., M.I.Mech.E., on Friday, January 2, 1948, with Dr. D. R. Pye, C.B., M.A., F.R.S., vice-president, in the chair. The subject is one that provides much scope for development and discussion, largely because of the changes effected as a result of improved materials for the cutting tools; and there are many important variables to be considered. Mr. Eatough regarded the subject from the point of view of the designer of machine tools, and indicated the nature of further improvements required in cutting tools. The primary consideration, he said, was to reduce the cost of production of the machined parts, which depended largely on increasing the rate of feed. This had been achieved by increasing cutting speeds, without increasing cutting loads, thereby easing the problem of the machine-tool designer. The introduction of high-speed steels and, later, tungsten-carbide tips, had revolutionised machine-tool design. The maximum spindle speeds had been increased, but it was still necessary to retain low speeds for forming operations, such as threading, owing to the very high loads imposed on the tool. Gearboxes had therefore been improved, and in one recent design it was possible to change speed during a cut, without leaving a mark on the surface of the work. A crater is formed near the edge of a tool, by the rapid passage of the chip, and Mr. Eatough gave the results of investigations into the rate of development of such craters. The effect of the peripheral length of cut, the speed of cutting, and the feed, were considered. For certain classes of turning, the grooved type of tool was more efficient than conventional types. It was a flat-topped negative-rake tool with a V-groove parallel to the cutting edge, and a narrow land between the groove and the edge. With most tools, there was some difficulty in disposing of the chip as it was formed so that the operator was not injured and the action of the tool and machine was not upset. One method, suited to the corkscrew-type chip, was to place an abutment in the path of the chip, immediately behind the tool, causing the chip to be broken into short lengths. The major problem, however, was due to the comparative brittleness of tungsten carbide; a tougher material was required. The slow speeds necessary in a machine tool for drilling, threading, etc., resulted in a complicated gearbox which absorbed as much as 40 per cent. of the power. In opening the discussion, Dr. F. C. Johansen, M.I.Mech.E., suggested that some information on the difficult operation of parting in the lathe would have been welcome, and he gave some results of an investigation into the influence on fatigue strength of different types of finish for the bores of locomotive tyres. Tyres made from steel of 50 to 65 tons per square inch tensile strength showed an increase of about 50 per cent. in bending fatigue strength when machined with carbide tools instead of high-speed steel tools.

THE BRITISH OVERSEAS AIRWAYS CORPORATION.

The annual report of the British Overseas Airways Corporation, unlike that of the British European Airways Corporation, reviewed on page 15, *ante*, covers a full year, as the Overseas Corporation dates from 1940, whereas the European Corporation was only established in August, 1946. In both cases, the periods covered by the reports ended on March 31, 1947. While, however, some allowance must be made for the facts that the Overseas Airways report relates to a period half as long again as that of the European Airways, that the route mileage is more than four times as long, and the total aircraft mileage about nine times as great, it is still rather painfully surprising to find that the operating loss is roughly four times that of the not inconsiderable deficit of the European Airways and a deficiency of 8,076,844*l.* is "carried to Ministry of Civil Aviation Account." As was the case with the earlier report, this one is well supplied with explanations of this very heavy loss, which are summarised as "multiplicity of types of uneconomical aircraft, . . . delay in the delivery of Tudors and consequent changes of plans, with their financial repercussions, scattered and improvised maintenance bases, . . . deficiencies in route organisation," the cost of development work, and a "programme of services in which commercial considerations were often subordinated to the national interest." The outstanding fact, the report concludes, "is that, with the present types of aircraft, even with a high load factor, receipts barely cover direct operating costs"; and it ends on the somewhat depressing note that "there is only one conclusion . . . Heavy deficits will inevitably continue until the Corporation has the aircraft and facilities to make it financially self-supporting in a highly competitive international business." Since the report was issued, it has been stated that the Corporation are negotiating with Trans-Canada Airlines for the acquisition of some of the latter company's DC.4M type of aircraft, which have proved successful on various Canadian services and which the manufacturers, the Canadian Company, are prepared to supply on favourable terms.

THE INSTITUTION OF MECHANICAL ENGINEERS (AUTOMOBILE DIVISION).

A general meeting of the Automobile Division of the Institution of Mechanical Engineers was held at the Institution, Storey's-gate, St. James's Park, London, S.W.1, on Tuesday, January 6, when Captain G. T. Smith-Clarke delivered his address as chairman of the Division. The address, which reviewed the progress of automobile engineering in the 43 years covered by Captain Smith-Clarke's personal experience, was divided into four parts, dealing, respectively, with heavy road vehicles in the decade from 1904 to 1914, the work of the automobile industry in the 1914-18 war, the design and development of the Alvis car, and the period from the outbreak of war in 1939 to the present day. Possibly the most striking feature of the historical review was the early date of certain constructional features, such as splined shafts, which are now accepted good practice in automobile engineering, and the relative slowness of their general adoption—due, perhaps, in some cases, to the effect of patent restrictions, but in others, it would seem, to a desire for originality, or to manufacturing limitations. In his brief reference to the part played by the automobile industry in developing the production of aero-engines during the war of 1914-18, Captain Smith-Clarke (who was then Officer-in-Charge of Engines, in the Coventry area, for the Aeronautical Inspection Directorate) mentioned, as an outstanding example, that the first British-built Gnome rotary engine was built from drawings and specifications based on a dismantled specimen engine, and ran on test a few hours less than eight weeks from the signing of the licence agreement between the Gnome Company, in France, and the Daimler Company, in England. With regard to the future of the automobile industry, he expressed the opinion that, so far as exports were concerned, there were markets throughout the world where British excellence in design and craftsmanship would command sufficient sales to meet requirements; but that the small engines characteristic of the British industry would never be acceptable to the car owner who had become accustomed to engines of three or four litres capacity. He considered that cars must be provided, as quickly as possible, in four main classifications, namely, a compact "family" car, about the size of the present 10-12 h.p. models, and a similar car of 18-20 h.p., in each case with a choice of either a 2-2½ litre or a 3-4 litre engine; sports cars, of 2½ to 3½ litres capacity, designed for the highest possible performance, trouble-free operation, and a reasonable life; and "super-luxury" cars which, he recognised, would sell only in comparatively small numbers. In general, he added, "British cars must be modern in line and treatment, but must remain British in appearance and most certainly must not ape the American."

ADMIRALTY RESEARCH ESTABLISHMENT.—The Admiralty announce that the largest of their research establishments, which under the name of Admiralty Signal Establishment, achieved world renown for its contribution to the development of radar, has now changed its name to the Admiralty Signal and Radar Establishment.

LETTER TO THE EDITOR.

ENGINEERING UNITS OF FORCE.

TO THE EDITOR OF ENGINEERING.

SIR,—There are two conceptions of "gravitational" units in engineering. In the first system, generally associated with the physicist, we have the fundamental units of mass, length and time, based on definite physical standards. The standard mass in the British system is the "pound" mass kept in London and accurately reproduced in replicas throughout the world. Sir Isaac Newton demonstrated that if a force F acted on a mass M and produced on it an acceleration a, then

$$F = K M a \quad . \quad . \quad . \quad (1)$$

where K is a constant depending on the choice of units. If we choose M = 1 pound, a = 1 ft. per sec. per sec., and K = 1, then F is called 1 poundal, which is the absolute unit of force. Hence if absolute units are used

$$F = M a \quad . \quad . \quad . \quad (2)$$

However, because of the importance of the force of gravity in engineering practice, and because the weight of a pound mass was commonly used in commerce, a "gravitational" unit of force has been introduced called the "pound weight," being the force of gravity on a standard pound mass or the "weight" of a pound. Thus in common engineering practice we have a tractive effort of so many pounds (not poundals) and stresses in pounds per square inch. To bring equation (1) into line with this system of units we interpret K as a numerical constant equal to $\frac{1}{g'}$, where g' is numerically equal to the acceleration due to gravity (g ft. per sec. per sec.) produced by a force of 1 pound weight acting on a pound mass.

Then

$$F' = \left(\frac{1}{g'}\right) M a. \quad . \quad . \quad (3)$$

This equation gives F′ in "lb. wt." units instead of poundals. As F′ is variable in terms of a variable "constant" g', and this may be undesirable, the value of g' is sometimes standardised at 32·2 for all places on the earth.

We may look at this matter a different way and say:

$$F' = M \left(\frac{a}{g'}\right) \quad . \quad . \quad . \quad (4)$$

where $\frac{a}{g'}$ is the acceleration in "gravities," or so many times the acceleration of gravity with dimensions of acceleration (ft. per sec. per sec.).

The second conception of gravitational units is attributed to Professor John Perry, some 60 years ago, and assumes as fundamental units those of force, length and time, with mass as a derived unit. The unit of force is the "pound" and the derived unit of mass is sometimes called the "slug" or the "gee-pound." The reasoning is generally as follows: "If the gravity force W acts alone on a particle it produces an acceleration g downwards. If W be replaced by a force F′ in any direction it follows that an acceleration a is produced in the direction of F′.

Then

$$\frac{a}{g} = \frac{F'}{W}. \quad . \quad . \quad . \quad (5)$$

and

$$F' = \frac{W a}{g}. \quad . \quad . \quad . \quad (6)$$

The factor $\frac{W}{g}$ is defined as the mass of the particle and is denoted by m with a unit of one "slug" and has dimensions of $\frac{\text{force}}{\text{acceleration}}$."

It will be noted that as the weight of a pound mass is one pound weight, then equations (4) and (6) are numerically equivalent, so that the introduction of a new unit of mass would seem to serve no good purpose. To get other opinions on this matter I wrote to civil and mechanical engineering societies in America and England for expert advice. From the limited replies I received I gathered the idea that in America, equation (6) is common practice, but use of a special term for the unit of $\frac{W}{g}$ is avoided. One American authority said, "It seems quite evident that it (the slug) is of little practical value in ordinary civil engineering practice. No engineer versed in structural or hydraulic theory and practice that I have contacted has had use for it—some never heard of it or forgot that they ever did. None of the lists of symbols used by them contains it . . . I can see no value for the use of such a unit except to be able to use one symbol, say m, instead of two (W and g). Against this is the fact that it is a unit without physical concept. This is also true of the term 'moment of inertia,' used very generally by civil engineers which has never seemed to require a specially named unit."

From English authorities, however, a definite reply was not forthcoming and it appeared to be a controversial matter there, with extreme views on both sides. I am hoping that there will be a clarification of the matter as a result of this correspondence. A very good treatment of the "anti-slug" case is found in the book by the late Dr. F. W. Lanchester, entitled *Theory of Dimensions and its Application for Engineers*. In this book the evolution of the "slug" is traced in three variants: (A) (as originally proposed by Professor Perry) defines the fundamental unit of force as the weight of a standard pound mass kept in London; (B) overcomes the variation of the force unit by standardising g as 32·2 ft. per sec. per sec.; and (C) takes mass, and not force, as the fundamental unit, defining the "slug" as g (or 32·2) times the standard pound mass. Lanchester's arguments against the "slug," as I have understood them, can be summarised briefly as follows:

(*a*) The fundamental unit (?) of force cannot conveniently be reproduced and standardised and sent in replica to all parts of the world as can the standard of mass. If we define force in terms of the standard mass, its claim to be a "fundamental" unit can be questioned.

(*b*) When the "slug" as a unit of mass is variable, depending on the value of g, such quantities as density, which depend on mass, will also become variable.

(*c*) If, on the other hand, g is standardised at 32·2, the system has no advantages over the "pound-poundal" system used by the physicist. (Equation (4) above.)

(*d*) It has not been found necessary on the Continent to coin such a word as "un escargot" as an equivalent in the c.g.s. system, to the "slug" in the f.p.s. system of units.

(*e*) The use of one word, "pound," for two things, mass and force, is not unique in the English language.

(*f*) A beam balance compares masses because their weights acting on either side are equal at the same place and time. To "weigh" things on such a balance we provide a set of standardised masses based on the London standard pound. If the "slug" is accepted as a unit of mass we must replace these sets of "weights" by sets based on the "slug."

(*g*) In dimensional analysis we assume the fundamental dimensions of M, L and T. If force is accepted as a fundamental unit instead of mass, then these fundamental dimensions must be altered to F, L and T.

(*h*) Many of the above disadvantages can be overcome if we adopt variant scheme (*c*) but in this case are we improving on the "pound-poundal" system by introducing still another unit—the "slug"?

(*i*) The spread of the "slug" idea has been largely as a result of indoctrination by enthusiastic students of Professor Perry who have, in their turn, become teachers.

Could the readers of ENGINEERING help me to decide, in the face of the above arguments, whether the introduction of the "slug" is justified, or whether we should rather revert to the simpler system of the physicist typified by my equation (4)?

Yours faithfully,

K. S. LENNIE.

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THE ESTIMATION OF STRESSES IN TURBINE-DISC RIMS.

By G. F. C. ROGERS.

(*Concluded from page 4.*)

FOR rims of a normal tapering form, the thickness at the disc end of the rim is of the order of three times that at the free end. Since the bending moment remains sensibly the same, the bending stress at the disc end will be about four-ninths of the values obtained for rims of constant thickness given in the tables. It should be noted that the figures in the table are of comparative value only, since no account has been taken of external blade loading. The examples given below show how the method may be applied to the two principal types of loading, namely, those obtaining in compressor discs and two-stage turbine discs. It must be stressed that the method is only approximate and is intended to give only a rough idea of the stresses involved.

EXAMPLES.

Two-Stage Turbine Disc.—The dimensions of the disc are given in Fig. 10, opposite. The centrifugal force acting on the blade and root material forms the loading on the rim, while the disc is loaded only from the material gashed to receive the blade roots. The design data are as follows: speed = 8,000 r.p.m.; $\rho = 0{\cdot}297$ lb. per cubic inch; $L_D = 84$ tons; $L_R = 213$ tons; $\frac{l}{r} = 0{\cdot}14$; $r = 9$ in.; $\frac{y}{r} = 0{\cdot}15$, therefore $A = 1{\cdot}13$ sq. in.; $\frac{2h}{r} = 0{\cdot}10$; $\frac{\text{hub width}}{\text{neck width}}$ of disc $= 2$; $K_D = \rho\frac{\omega^2}{g} = 0{\cdot}241$; $K_R = K_D + \frac{L_R}{2\pi r^2 A} = 0{\cdot}241 + 0{\cdot}371 = 0{\cdot}61$; $\frac{K_D}{K_R} = 0{\cdot}395$.

The equations for matching the curves for the disc and rim are:—

$$\left[\frac{w_1 E}{r^3 K_R}\right] = \left[\frac{w E}{r^3 K_D}\right]\frac{K_D}{K_R}$$

and

$$\left[\frac{2 F_1}{r^3 K_R}\right] = \left[\frac{U}{r^3 K_D}\right]\frac{K_D}{K_R} - \frac{L_D}{2\pi r^4 K_R}.$$

If the disc curve for this particular value of $\frac{y}{r}$ is superimposed on the rim curve for the given values of $\frac{2h}{r}$ and $\frac{l}{r}$, the point of intersection of the two curves will give the working conditions. From the disc curve, when $\frac{U}{r^3 K_D} = 0$, $\frac{w E}{r^3 K_D} = 0{\cdot}149$, the corresponding point on the co-ordinates of the rim curves becomes

$\frac{2 F_1}{r^3 K_R} = -0{\cdot}0033$, $\frac{w_1 E}{r^3 K_R} = 0{\cdot}0588$, from the matching equations.

Similarly, when

$$\frac{U}{r^3 K_D} = 0{\cdot}07 \text{ and } \frac{w E}{r^3 K_D} = 0{\cdot}4$$

$$\frac{2 F_1}{r^3 K_R} = 0{\cdot}0244 \text{ and } \frac{w_1 E}{r^3 K_R} = 0{\cdot}158.$$

Fig. 11, opposite, shows this line plotted on the rim curves, and the curves intersecting at the point where $\frac{w_1 E}{r^3 K_R} = 0{\cdot}155$. The bending stress may be read off the rim curve, the non-dimensional value being 0·48; hence, the bending stress for a rim of rectangular cross-section is $0{\cdot}48\, r^3 K_R = 23$ tons per square inch. The order of the bending stress to be expected from a rim section with increased thickness at the disc end (say, one and a half times the assumed thickness) is then about $\frac{4}{9} \times 23 \simeq 10$ tons per square inch. The disc hoop stress may be read off the disc curves if the working point is transferred to Fig. 5, on page 1, *ante*.

Since

$$\frac{w_1 E}{r^3 K_R} = 0{\cdot}155, \frac{w E}{r^3 K_D} = 0{\cdot}393$$

STRESSES IN TURBINE-DISC RIMS.

Fig. 10.

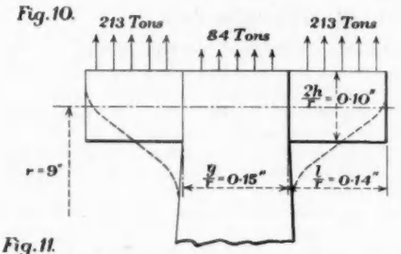


Fig. 12.

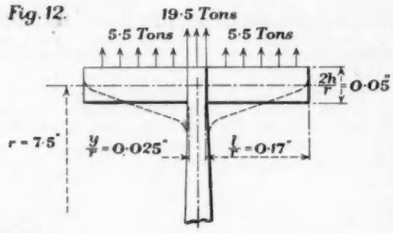


Fig. 11.

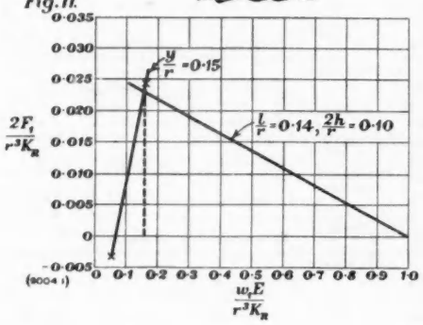


Fig. 13.

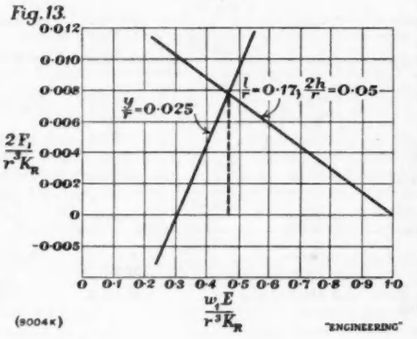


Fig. 14.

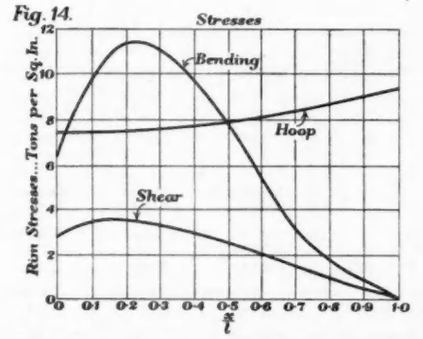
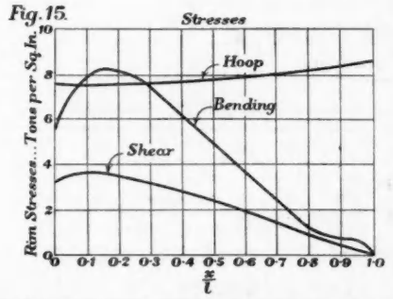
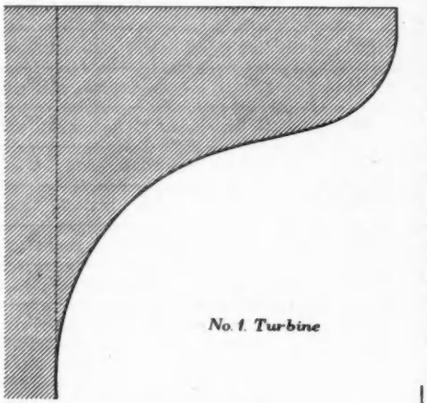
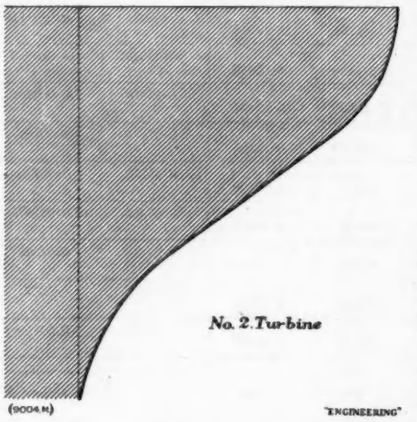


Fig. 15.







and the hoop stress is $0{\cdot}53\,r^2\,K_D \simeq 10$ tons per square inch.

Compressor Disc.—The dimensions of the disc are given in Fig. 12, on this page. In this example, it is assumed that the blade loading is taken directly by the disc, while the rims are loaded only from the fact of being gashed to take the blade roots. The data are: speed = 7,500 r.p.m.; $\rho = 0{\cdot}1$ lb. per cubic inch; $L_D = 19{\cdot}5$ tons; $L_R = 5{\cdot}5$ tons; $\frac{l}{r} = 0{\cdot}17$; $r = 7{\cdot}5$ in.; $\frac{2h}{r} = 0{\cdot}05$, therefore $A = 0{\cdot}48$ sq. in.; $\frac{y}{r} = 0{\cdot}025$; $\frac{\text{hub width}}{\text{neck width}}$ of disc = 2; $K_D = \frac{\rho w^2}{g} = 0{\cdot}071$; $K_R = K_D + \frac{L_R}{2\pi r^3 A} = 0{\cdot}071 + 0{\cdot}033 = 0{\cdot}104$; $\frac{K_D}{K_R} = 0{\cdot}683$.

As in the preceding example, where $\frac{U}{r^2 K_D} = 0$ and $\frac{w E}{r^2 K_D} = 0{\cdot}149$, the corresponding point on the co-ordinates of the rim curve will be $\frac{2F_1}{r^2 K_R} = -0{\cdot}0094$, $\frac{w_1 E}{r^2 K_R} = 0{\cdot}102$. Similarly, $\frac{U}{r^2 K_D} = 0{\cdot}03$, and $\frac{w E}{r^2 K_D} = 0{\cdot}79$, corresponding to $\frac{2F_1}{r^2 K_R} = 0{\cdot}0111$ and $\frac{w_1 E}{r^2 K_R} = 0{\cdot}54$.

Fig. 13, on this page, shows the working point to be where $\frac{w_1 E}{r^2 K_R} = 0{\cdot}47$. Reference to Fig. 4, on page 1, *ante*, then gives the bending stress to be $0{\cdot}75\,r^2 K_R \simeq 4{\cdot}4$ tons per square inch for a rim of rectangular cross section; thus the stress to be expected from a normal tapered rim is $\frac{4}{9} \times 4{\cdot}4 \simeq$ 2 tons per square inch. Since $\frac{w_1 E}{r^2 K_R} = 0{\cdot}47$, $\frac{w E}{r^2 K_D} = 0{\cdot}69$, and reference to Fig. 9, page 3, *ante*, gives a disc hoop stress of $1{\cdot}0\,r^2 K_D \simeq 4$ tons per square inch.

Method of Iteration for Tapered Rims.—Since a simple analytical method cannot be used for rims of variable thickness, the method of iteration is employed. Briefly, this consists of assuming an initial variation of the deflection of the rim over its width, working through four integrations graphically to obtain a better approximation to the deflection, and repeating the process using the more accurate deflection curve. The values of the deflection converge fairly rapidly, and only two or three approximations will be found to be necessary. The final two successive deflection curves will be parallel to one another, and the stresses in the disc rim may then be found from values of the deflection corresponding to the mean of these curves. A straight-line variation of deflection may be assumed for the first approximation. Let the suffixes 1, 2, 3, etc., denote the successive approximations of the quantities to which they are appended. Considering an element of the rim of length dx and equating forces and moments, we have:—

$$\frac{d^2 M_1}{dx^2} = K\,2h\,r - E\,\frac{2h\,w_1}{r^2}.$$

In this case, $2h$ is a function of x and so, on integrating, this becomes

$$\frac{M_1}{r^4 K} = \iint \left\{ \frac{2h}{r^3} - \frac{2h}{r^3}\,\frac{w_1 E}{r^2 K} \right\} dx\,dx.$$

Putting this into non-dimensional form, if $\phi = \frac{x}{l}$,

$$\frac{M_1}{r^4 K} = \left(\frac{l}{r}\right)^2 \iint \left\{ \frac{2h}{r} - \frac{2h}{r}\,\frac{w_1 E}{r^2 K} \right\} d\phi\,d\phi. \qquad (8)$$

Now $M = \frac{E}{1-\sigma^2} I \left\{ \frac{d^2 w}{dx^2} + \frac{\sigma w}{r^2} \right\}$,

therefore

$$\frac{M}{r^4 K} = \frac{E}{1-\sigma^2}\,\frac{2h^3}{3r^4 K} \left\{ \frac{d^2 w}{dx^2} + \frac{\sigma w}{r^2} \right\}$$

$$\frac{E}{r^3 K}\,\frac{d^2 w}{dx^2} = \frac{M}{r^4 K}(1-\sigma^2)\frac{3}{2}\,\frac{r}{h^3} - \frac{w E \sigma}{r^3 K r^3}.$$

Putting in the value of 0·3 for σ and integrating, we have

$$\frac{E}{r^3 K} w_2 = \frac{1}{r^3} \iint \left\{ \frac{M_1}{r^4 K}\,1{\cdot}365\,\frac{r^3}{h^3} - \frac{w_1 E}{r^3 K}\;0{\cdot}3 \right\} dx\,dx,$$

and, non-dimensionally,

$$\frac{w_2 E}{r^3 K} = \left(\frac{l}{r}\right)^2 \iint \left\{ \frac{M_1}{r^4 K}\,\frac{10{\cdot}92}{\left(\frac{2h}{r}\right)^3} - 0{\cdot}3\,\frac{w_1 E}{r^3 K} \right\} d\phi\,d\phi. \qquad (9)$$

Thus, knowing the variation of $2h$ with x, and assuming a variation of the deflection with x, (w_1), a better approximation for the deflection (w_2) can be calculated. The integrations may be carried out in tabular form, as shown in Table III, on page 42, by dividing the rim into a number of strips of equal width.

Providing that the integrations are carried out from the correct end of the rim, in conformity with the initial condition (shear force and bending moment zero at $x = l$, and slope zero at $x = 0$), w_2 may be found in terms of a single integration constant A. This constant may be determined from the conditions at the interface of the rim and disc by the method given on page 2, *ante*.

As they stand, the above expressions refer to rims which have no external loading applied. As in the analytical method, the rim loading may best be taken into account by substituting K_R for K, where

$$K_D = K + \frac{L_R}{2\pi r^3 x \text{ shaded area in Fig. 3, page 1, } ante}.$$

Having determined A_1, column (22) can be completed, giving $\frac{w_2 K}{r^2 K_R}$, the deflection which is to be used for the next approximation. This column (22) is transferred to column (3) and the whole process repeated. Only two or three approximations will be necessary. The last two deflection curves will run parallel, and the mean value of the correspond-

STRESSES IN TURBINE-DISC RIMS.

TABLE III.—STRESSES IN NO. 1 DISC HEAD (ITERATION METHOD): LAST APPROXIMATION.

Speed = 8,000 r.p.m. Ld. = 52·6 tons. Lr. = 166 tons. Radius of C.G. of one rim = r = 9·61 in. Area of cross-section of one rim = 0·721 sq. in. $\frac{l}{r}$ = 0·13. $K = p\frac{w^2}{g}$ = 0·240, y = 1·11 in.

1. $\psi = \frac{x}{l}$	2. $\frac{2h}{r}$	3. $\frac{w_2 E}{r^3 K_R}$	4. (2) × (3)	5. (2) − (4)	6. − (5) $d\psi$	7. $-\int$ (5) $d\psi$	8. Mean of − (7)	9. (8) $d\psi$	10. $\iint$ (5) $d\psi\, d\psi$	11. $\left(\frac{l}{r}\right)^2 \times$ (10)	12. $\left(\frac{2h}{r}\right)^3$	13. $\frac{(11)}{(12)} \times 10{\cdot}92$
0	0·1417 0·1163					0·05215			0·020088			
		0·1266	0·01472	0·10158	0·01016		0·04707	0·004707		0·000299	0·00157	2·08
0·1	0·0910 0·0845					0·04199			0·015381			
		0·1271	0·01074	0·07376	0·00738		0·03830	0·003830		0·000225	0·000603	4·07
0·2	0·0781 0·0723					0·03461			0·011551			
		0·1282	0·00926	0·06304	0·00630		0·03146	0·003146		0·000169	0·000378	4·89
0·3	0·0666 0·063					0·02831			0·008405			
		0·1301	0·00819	0·05481	0·00548		0·02557	0·002557		0·000120	0·000253	5·18
0·4	0·0594 0·0567					0·02283			0·005848			
		0·1329	0·00753	0·04917	0·00492		0·02037	0·002037		0·0000816	0·000182	4·90
0·5	0·0541 0·0525					0·01791			0·003811			
		0·1365	0·00717	0·04533	0·00453		0·01560	0·001560		0·0000512	0·000145	3·86
0·6	0·051 0·0495					0·01338			0·002251			
		0·1407	0·00696	0·04254	0·00425		0·01125	0·001125		0·0000285	0·000121	2·574
0·7	0·0479 0·0469					0·00913			0·001126			
		0·1452	0·00681	0·04009	0·00401		0·00712	0·000712		0·0000122	0·000103	1·292
0·8	0·0458 0·0417					0·00512			0·000414			
		0·1501	0·00626	0·03544	0·00354		0·00335	0·000335		0·00000416	0·0000725	0·626
0·9	0·0375 0·0188					0·00158			0·000079			
		0·1551	0·00291	0·01584	0·00158		0·00079	0·000079		0·000000668	0·0000066	1·106
1·0	0					0			0			

TABLE III—*continued.*

14. 0·3 × (3)	15. (13) − (14)	16. (15) $d\psi$	17. $\int$ (15) $d\psi$	18. Mean of (17)	19. (18) $d\psi$	20. $\iint$ (15) $d\psi\, d\psi$	21. $\left(\frac{l}{r}\right)^2 \times$ 20.	22. (21) + A.	23. Bending Stress.	24. Shear Stress.	25. Hoop Stress.
0·03798	2·0420	0·20420	0	0·1021	0·01021	0	0	0·1265	6·17	2·83	7·43
0·03813	4·03187	0·403187	0·2042	0·40579	0·04058	0·01021	0·0001725	0·1267	9·52	3·54	7·44
0·03846	4·8515	0·48515	0·60739	0·84991	0·08499	0·05079	0·000858	0·1274	11·32	3·41	7·50
0·03903	5·1410	0·51410	1·09254	1·34959	0·13496	0·13578	0·002292	0·1288	11·10	3·26	7·55
0·03987	4·8601	0·48601	1·60664	1·84964	0·18496	0·27074	0·00457	0·1311	9·87	2·96	7·70
0·04095	3·8191	0·38191	2·09265	2·2836	0·22836	0·45570	0·00770	0·1342	7·80	2·54	7·89
0·04221	2·5318	0·25318	2·47456	2·60115	0·26012	0·68406	0·0115	0·1380	5·36	2·01	8·11
0·04356	1·2484	0·12484	2·72774	2·79016	0·27902	0·94418	0·01595	0·1425	3·08	1·46	8·37
0·04503	0·5810	0·05810	2·85258	2·88163	0·28816	1·22320	0·0207	0·1472	1·45	0·87	8·66
0·04653	1·0595	0·10595	2·91068	2·96366	0·29637	1·51136	0·0255	0·1520	0·76	0·33	8·94
			3·01663			1·80773	0·0305	0·1570	0	0	9·24

To find A :—

$$K_R = 0{\cdot}240 + \frac{166}{2\pi\, 9{\cdot}61^3\, 0{\cdot}721} = 0{\cdot}639$$

$$\frac{U}{r^3 K_D} = \frac{0{\cdot}639}{0{\cdot}240}\left[2 \cdot 0{\cdot}13\ 0{\cdot}05215 + \frac{52{\cdot}6}{2\pi\, 9{\cdot}61^4\, 0{\cdot}639}\right] = 0{\cdot}040, \text{ from equations (6) and (7).}$$

From Fig. 9, $\frac{w^2 E}{r^3 K_D} = 0{\cdot}337$. Hence, $A_2 = 0{\cdot}337 \times \frac{0{\cdot}240}{0{\cdot}639} = 0{\cdot}1265$ from equation (8).

ing bending-moment curves is used for plotting the distribution of bending stress.

The stresses will be given by the following equations :—

$$\text{Bending stress} = \frac{M\,h}{\frac{1}{6}h^3} = \frac{(11)\,6}{(2)^3} r^2 K_R \text{ tons per sq. in.} \quad . \quad . \quad (10)$$

$$\text{Shear stress} = \frac{F}{2h} = \frac{\frac{l}{r} \times (8)}{(2)} r^2 K_R \text{ tons per sq. in.} \quad . \quad . \quad (11)$$

$$\text{Hoop stress} = E\frac{w}{r} = (22)\, r^2 K_R \text{ tons per sq. in.} \quad . \quad . \quad (12)$$

The figures in circles refer to the mean of the figures, in the respective columns, of the last two approximations. An example showing the calculation is given in Table III, herewith, where the final approximation of the calculation for No. (1) turbine disc is set out.

Determination of the Constant of Integration.—The boundary condition, which enables the constant of integration to be determined, is that of equal radial extension for the rim and disc at the interface.

The non-dimensional value of the pull which the rim exerts upon the disc is given by :—

$$\frac{2F_1}{r^3 K_R} = 2\frac{l}{r}[(7)]_{\frac{x}{l}=0}' \quad . \quad . \quad (13)$$

where $[(7)]_{\frac{x}{l}=0}$ refers to the figure given in column (7) of the table, for the condition $\frac{x}{l} = 0$.

If the external load on the disc is L_D tons, then the load per inch of circumference is $\frac{L_D}{2\pi r}$ and the total pull on the disc becomes :

$$U = 2F_1 + \frac{L_D}{2\pi r};$$

or, non-dimensionally,

$$\frac{U}{r^3 K_R} = \frac{2F_1}{r^3 K_R} + \frac{L_D}{2\pi r^4 K_R}.$$

The left-hand side of the equation will be required

in terms of the disc constant $K_D \left(= \rho \frac{\omega^2}{g}\right)$ so this becomes:—

$$\frac{U}{r^3 K_D} = \frac{K_R}{K_D}\left[\frac{2 F_1}{r^3 K_R} + \frac{L_D}{2 \pi r^4 K_R}\right] \quad . \quad (14)$$

The disc extension for this pull may then be calculated from first principles or obtained from Figs. 8 and 9, on page 3, *ante*. These figures give families of curves, for different neck widths, of the radial extension plotted against disc pull for parallel-sided solid discs and for straight-sided tapered solid discs, respectively. The value of the extension taken from the appropriate curve will be in the non-dimensional form

$$\frac{w E}{r^3 K_D},$$

The extension of the rim will be given by

$$\frac{w_2 E}{r^3 K_R} = \left[(21)_{\frac{x}{l}=0} + A_1\right].$$

If the last integration was carried out from the correct end of the rim (that is, from $\frac{x}{l} = 0$), then $(21)_{\frac{x}{l}=0} = 0$. (See Table III, opposite.)

From the boundary condition of equal radial extensions we have:

$$\frac{w E}{r^3 K_D} = \left[\frac{w_2 E}{r^3 K_R}\right]\frac{K_R}{K_D}.$$

Hence,

$$A_1 = \left[\frac{w E}{r^3 K_D}\right]\frac{K_D}{K_R} \quad . \quad . \quad (15)$$

Stresses in Two Turbine Disc Rims.—The method of iteration has been applied to the two turbine discs, and the distribution of the stresses in the rims are shown in Figs. 14 and 15, on page 41. For the purpose of finding the constants of integration (A), a disc taper (hub/neck, width ratio) of 2·0 was used. In both cases, the discs are solid. The rim hoop stress is slightly less than the maximum bending stress and is of the same order as the hoop stress in the disc. The peak bending stress, and also the amount of variation of hoop stress over the width of rim, is greater in the case of No. (1) turbine rim owing to the more gradual taper of the rim. However, since all the variables are different in both cases, it is not intended that a comparison of the two discs be made. The results are given merely to show the order of stresses involved and the type of variation over the width of rim. It should be remembered that the hoop stress curve is equivalent to the deflection curve.

In conclusion, it will be seen that the shear stress in the rim is small compared with the bending stress in all practical cases, while the hoop stress in the rim is sensibly constant over its width and is slightly lower than the hoop stress in the disc at the same radius. The rim bending stress is the most important stress and is very sensitive to the amount of rim overhang and the thickness of the rim. A guide to the thickness of rim for a given overhang can be obtained from the examples given in Tables I and II, pages 2 and 3, *ante*, which give the stresses for rims of constant thickness, and the first two worked examples show how the curves, Figs. 4 to 9, pages 1, 2 and 3, *ante*, can be used to obtain the order of the stresses obtaining in any given disc and rim.

BRITISH COAL OUTPUT DURING 1947.—It is announced that the output of British coal mines during the 53 weeks of 1947 was 199,700,000 tons, or 300,000 tons less than the target figure. Production during the corresponding period of 1946 was 191,790,000 tons.

TRIAL RUN OF STAINLESS-STEEL COACH.—The "Silver Princess" stainless-steel coach formed part of the 10 a.m. "Flying Scotsman" from King's Cross on Thursday, January 1, 1948. The coach, which was illustrated and described on page 584 of our issue of December 19, 1947, is a prototype manufactured by the Budd Company, Philadelphia, U.S.A., for the Pressed Steel Company, Cowley, Oxford, who intend to build similar coaches in this country. Owing to the double glazing of the windows, and the sound-insulating material used in the body, the noise in the coach while running is noticeably less than that experienced in a coach of conventional design. No "drumming" of the metal body was heard during the run to Peterborough.

HIGH-VOLTAGE POWER TRANSMISSION IN SWEDEN.

ON Wednesday, May 14, 1947, a lecture entitled "Recent Research and Development Work in Sweden on High-Voltage Alternating and Direct-Current Power Transmission" was delivered by Dr. W. Borgquist before the Transmission Section of the Institution of Electrical Engineers. No report of this lecture was made at the time and the text has only recently become available. Considering the importance of this subject in relation to possible future developments in this country, an abridged account of the lecturer's remarks is given below.

The backbone of the existing 220-kV system, said the lecturer, consisted of four trunk lines running from Indalsalven in the north to the south of Sweden. Two new lines for the same voltage were under construction. The northern end of this system was connected to a network, which was designed for 132 kV, and in the south, it was connected to 132-kV and 77-kV networks and new 220-kV lines were also being constructed. The average length of the 220-kV north to south lines was 220 miles, and the normal average load carried during the winter was 135 MW to 145 MW, with a peak load of from 145 MW to 160 MW. The system had proved dynamically stable on most of the faults that had occurred. The possibilities of 220 kV had, therefore, been carefully investigated before it was decided to use a higher value. The employment of this higher value arose from the decision to develop the falls at Harspranget, where a head of 360 ft. was to be utilised in a high-efficiency station with a capacity of 285 MW. A voltage of 220 kV would have been too low to transmit power 600 miles from this station to the south, especially as it was undesirable to use more than one line for this purpose. The alternatives of direct current at 2 × 250 kV and alternating current at between 330 kV and 44 kV for this purpose had, therefore, been carefully discussed.

Provided that reliable converter stations could be constructed at a moderate cost, long-distance transmission could be effected more simply and economically with direct than with alternating current, owing to the fact that with the former there were no stability limitations and the lines could, therefore, be loaded up to the economic limit. As a result, line costs were reduced. Among other advantages was the possibility of using underground cables for long-distance transmission. In 1943, therefore, the Swedish State Board decided to erect an experimental direct-current transmission scheme using 90 kV to transmit a current of 70 amperes. Delays, due to lack of materials and other reasons, prevented this scheme from being put into operation before October, 1945, and the experience gained with it had, therefore, been limited. Further, the unexpectedly rapid increase in power consumption made it necessary for the erection of the Harspranget line to be begun in 1947, with the result that the idea of using direct-current on it had to be abandoned and three-phase alternating current at 380 kV was to be utilised instead.

There was, however, no conclusive reason why direct-current should be used unless the transmission distance was at least 350 miles, or there were special reasons for employing underground cables. Only mercury converters should be considered and the general opinion appeared to be that a constant transmission voltage should be employed. At the Swedish experimental plant, the sending and receiving stations contained two converters, each of which consisted of six valves in double-way six-phase connection. By connecting several converters of this type in series it was possible theoretically to produce any direct-current voltage. Although opinions differed on this subject, in Sweden an inverse voltage of 62·5 kV per valve and an anode current of 80 amperes had been adopted. When using valves with five anodes these figures gave a voltage of 62·5 kV, a current of 400 amperes and an output of 25,000 kW from each converter. In order to neutralise unavoidable back-fires, two or more valves could be connected in series or the number of converters might be such that one could be temporarily by-passed if a fault occurred in it. The former method involved a high cost for valves, while the latter required a perfect automatic protection device. Assuming that either or both of these conditions could be fulfilled the question arose whether a high-voltage valve could operate under full load year after year without serious ageing. It was, however, too soon to answer this. The economy of direct-current transmission was unfavourably affected by the costs of the large phase compensation which was necessary at the receiving stations. The reactive power consumption of the inverter amounted, in kilovolt-amperes, to at least 55 per cent. of the active power transmitted in kilowatts. Further, the whole reactive power needed in the receiving network had to be produced in this network, as no reactive power could be transmitted over the direct-current line.

As already mentioned, the next development on the Swedish system would be the use of very high alternating-current voltages. Calculations had been made for 330, 380 and 440 kV, using, in each case, single, double and triple conductors. These calculations were based on the assumption that the new voltage would be utilised on all the lines which would be erected between Norrland and central and south Sweden, that the total load would be 2,000 MW, and that the average transmission distance would be 450 miles. While it appeared that the first costs, as well as the annual transmission losses, were reduced as the voltage increased, the difference in the case of the three voltages mentioned was not great. Double conductors were economically preferable to either the single or triple conductor. As usual, the final choice was a matter of taste, and 380 kV was selected, partly because the length of the lines which would be erected initially would be only 350 miles, for which distance this figure was high enough. The system would be operated with a solidly earthed neutral, as the construction of transformers with an isolated neutral for connection to arc-suppression coils gave rise to insuperable difficulties.

The station at Harspranget would be equipped with three 105-MVA alternators running at 167 r.p.m. and generating three-phase current at 16 kV and a power factor of 0·9. The machines would be of the vertical-shaft umbrella type and would supply a bank of three single-phase transformers with a reactance of 10 per cent. At Hallsberg—the southern end of the line—there would be two 250-MVA single-phase transformer banks, which would step the 380 kV down to 220 kV. There would also probably be an 11-kV winding for supplying the reactors and synchronous machinery. At Midskog, in the middle of the line, there would be a transformer bank of the same capacity and voltages, through which a connection would be made to the power system at Indalsalven. The reactance of these transformers would be 12 per cent. As the knowledge of corona and switching difficulties at 380 kV was very limited, it had been considered desirable to arrange for the line to be operated at, say, 350 kV when switching in, at low load, or if corona or radio disturbances became excessive. On the other hand, it might be desirable to operate at a higher value if experience showed this to be desirable. Rather wide regulation would therefore be provided in the neutrals of the 380-kV windings at all three of the places mentioned above by means of separate regulation transformers. At Hallsberg and Midskog, voltage regulation would also be necessary to meet the requirements of the 220-kV systems, while at Midskog the angle between the 380-kV and 220-kV vectors would have to be regulated, in order that the load might be economically divided between the 380-kV and 220-kV lines that were connected in parallel Shunt reactors of 120 MVA would be installed at Harspranget, and of 200 MVA at Midskog and Hallsberg, to compensate the capacity current at no load or low load. The circuit breakers would be of the air-blast type, with an interrupting capacity of about 10,000 MVA. It was hoped to be able to use high-speed single-phase units with automatic reclosing, but this matter had not yet been fully investigated. The 380-kV equipment would be required to withstand a one-minute test at 760 kV alternating-current and an impulse test of 1,775 kV.

The transmission line would comprise two conductors per phase, each conductor consisting of 0·11 sq. in. of steel and 0·81 sq. in. of aluminium with an outer diameter of 1·25 in. The spacing between the conductors would be 17·7 in. and the normal span 1,100 ft. The towers would be made of high-grade galvanised steel, and for this reason the cost would be only slightly more than that of the towers used on the first 220-kV lines. Two steel earth wires, each with a cross section of 0·11 sq. in., would be used and would be placed to give a shielding angle of 24 deg. Radial cables would be embedded in the soil at the foot of the towers to provide a low footing resistance. The insulator strings would be 11 ft. long and would consist of 23 units of the American type or 20 units of the Swedish type. The cost of the complete line was estimated to be 9,000*l.* per mile. The ohmic transmission losses would be very small, owing to the large cross-sectional area of the conductors, and would, in fact, only amount to about 6·5 per cent. when transmitting 300 MW over 600 miles. It had been difficult to estimate the extent of the corona losses owing to the considerable variation in weather conditions which might occur along the line. They would, of course, normally be small compared with the ohmic losses, but might occasionally be of similar magnitude.

COKE-OVEN PLANTS FOR SOUTH AFRICA.—Messrs. The Woodall-Duckham Vertical Retort and Oven Construction Company (1920), Limited, Ebury House, 150, Victoria-street, London, S.W.1, announce that they have now under construction, for the South African Iron and Steel Industrial Corporation Limited, coke-oven and by-product recovery plant valued at over 2,250,000*l.*

NEW WORKS FOR MIRRLEES-IMO PUMPS.

At the invitation of Messrs. Mirrlees-Watson Company, Limited, and Aktiebolaget Imo-Industri, we had an opportunity recently of inspecting the new works of Messrs. Mirrlees (Engineers), Limited, Earl Haig-road, Hillington, Glasgow, S.W.2. These works, which are on one floor, are situated on the Hillington Industrial Estate, and they have been acquired and laid out expressly for the manufacture of screw pumps to the Imo design and patents. As this pump was described, with a sectional drawing, in ENGINEERING, vol. 146, page 515 (1938), only a brief reference to its main features need be made here. The Imo pump is of the screw type, and consists of three long screws, which mesh together closely and revolve in three bores in the body of the pump. The central screw is the driven member and it drives two diametrically-opposite side screws, which serve as seals for the liquid being pumped. There are, therefore, only three moving parts, and as the assembled screws function as a continuous piston, the liquid is propelled without turbulence or rotation, and the pump is self-lubricating. The Imo pump is available in three main types, for low, medium, and high pressures, and there are other special types for particular duties, such as the pumping of milk, water, beer and molasses. The standard pumps are suitable for pumping oily water, fuel oil and lubricating oil, and their uses include the circulation of the latter fluids, the operation of hydraulic rams and oil-burning systems, and the bulk handling of oil and viscous fluids. The pumps are made in a wide range of capacities and pressures; the capacities being from a few gallons up to 600 tons per hour, at pressures up to 2,500 lb. per square inch, when pumping lubricating oil. The Imo pump is normally driven by an electric motor or a turbine, and the makers claim that it is self-priming, quiet and free from vibration, and that, in handling fuel oil and lubricating oil, efficiencies up to 80 per cent. and 90 per cent., respectively, have been obtained.

THIRD-CLASS SLEEPING CAR FOR THE L.N.E.R.

On Wednesday, December 31, 1947 (the day before nationalisation), the London and North Eastern Railway Company showed a new third-class sleeping car at King's Cross station. The arrangement of the compartments and berths is new, and is intended to use the limited space to the best advantage. Most of the bulkheads between adjacent compartments have a horizontal "shelf" at about half the height of the coach body, the bulkhead above being fastened to one edge of the shelf, and that below being fastened to the other edge. The berth in one compartment rests on the shelf, and that in the other compartment is below it and is raised 9 in. off the floor. It has thus been possible to provide four double-berth compartments, and eight single-berth compartments—a total of 16 berths. Two lavatories at one end of the coach, and a compartment for an attendant at the other end, are also provided. In the past, the sleeping accommodation for third-class passengers consisted of four berths to a compartment, with only rugs and pillows, but the new coach is almost as comfortable as a first-class coach. Each compartment is fitted with a wash basin, "Punkah Louvre" adjustable blowers for admitting warm or cold air, and an ordinary steam-heated radiator controlled by the passenger.

The heating and ventilating equipment has been provided by Messrs. Thermotank, Limited, 150, Helen-street, Glasgow, S.W.1. Current for heating water is generated by a 50-volt, 100-ampere dynamo, and current for lighting and ventilating is generated by a 24-volt, 125-ampere dynamo, both driven by belts from pulleys on the axles. Batteries are included in each circuit. The usual fittings are provided for the passengers, and there are also two illuminated signs (one for each lavatory), which indicate whether the toilet is engaged or vacant. The signs can be seen from any part of the side corridor of the coach, and are actuated by the movement of the door lock, the locking bar pressing a switch incorporated in the socket. The coach is built on a standard four-wheeled bogie frame, 65 ft. in length over the head-stocks, 66 ft. 6 in. in length over the body, and 68 ft. in length over the vestibules. The centre-lines of the bogies are 47 ft. apart, and the total weight of the coach is 41 tons. The body is timber framed, faced with steel panels. The bogies are of the compound-bolster type; the journal size is 10 in. by 5 in., and the wheelbase of each bogie is 8 ft. 6 in. Buckeye-type couplers and Pullman vestibule gear are fitted. The coach was built in ten weeks at the Doncaster Works, under the supervision of the Chief Mechanical Engineer, Mr. A. H. Peppercorn, O.B.E., M.I.Mech.E., and it is the first of six to be constructed.

LABOUR NOTES.

In a New Year Message to the miners, Mr. Lawther, President of the National Union of Mineworkers, says: "We enter 1948 with more than ordinary hopes. We have passed the first milestone in our nationalised industry. All the fears of the ultra-pessimist have been smashed by your actions. Your faith in the era that began a year ago was as intense as the diehards' hatred of the change. Your deeds, the records you have broken, entitle you to an honourable place in the community. At long last, everyone realises that the salvation of this country depends upon your efforts. In spite of the hollow arguments of the critics of the National Coal Board, you know from experience that during 1947 more changes have taken place to improve your lot than in any one year in the history of the industry. You have the assurance of the Board that steps will be taken by way of increased supplementary compensation payments, to improve the position of those of you who meet with injury or who suffer from industrial disease."

"The union," Mr. Lawther went on to say, "will also press for payment of a pension from the industry, in addition to that provided by the State to those of you who have spent your lives in Britain's premier industry. There are further improvements that a nationally-owned industry will give to those who provide the heat and energy for Britain's industry. Your efforts are an example to a stricken world struggling to rehabilitate itself. You have done a good job during 1947. Continue the good work. . . . Let everyone in the industry, in whatever sphere he operates, resolve that no action of his during 1948 shall interfere with the production capacity of the industry or impair the supply of coal needed by Britain for her recovery."

In a New Year Message to the miners of Northumberland, Mr. James Bowman, the secretary of the Northumberland area of the National Union of Mineworkers, and a vice-president of the union, congratulated them on a strike-free year. Their confidence, he added, in the new conciliation machinery was shown by the great volume of work which had been handled by the disputes committee.

According to the Ministry of Labour and National Service, the index of retail prices, which, in June last year, took the place of the old cost-of-living index, rose two points between October 14 and November 18. The November figure was 103. The rise was mainly accounted for by increased prices for sugar, tomatoes, other fresh vegetables and apples, and by the effect of the recent increase in the cost of alcoholic drink. Based on retail prices collected on June 17 (100), the index figure was 101 in July, 100 in August, 101 in September, and 101 in October.

Largely on behalf of the 125,000 weavers in the industry, the Northern Counties Textile Trades Federation have applied to the Cotton Manufacturers' Association for a joint meeting to consider paying the whole of the weaving section higher wages on a basis identical with that conceded recently to the spinners and card-room workers.

Speaking at Birkenhead last week, after the launch by Messrs. Cammell Laird and Company, Limited, of the new passenger and cargo liner Ceramic for the Shaw Savill and Albion Line, Sir Robert Johnson, chairman and managing director of Messrs. Cammell Laird and Company, Limited, said that during the negotiations on the subject of the 44-hour week, the trade-union representatives had promised to give greater output. That promise had not been fulfilled. On the contrary, output at Birkenhead had decreased, and absenteeism had increased between 9 per cent. and 10 per cent. daily. "If," he declared, "we could get back to pre-war standards, we could build nine ships where we are now building six."

In December, it will be recalled, the General Council of the Trade Union Congress adopted unanimously an interim report by the special economic committee appointed to discuss wages, prices, subsidies, and related problems with the Prime Minister, the Chancellor of the Exchequer, and other members of the Government. Copies of the interim report have now been circulated to the executives of the affiliated unions for their study. It is insisted in the document that cost-of-living subsidies must be maintained and that there must be no interference with traditional trade union rights to negotiate wage agreements on behalf of their members as they think fit. The unions, however, are reminded that without a sufficient increase in output, and a large-scale expansion of exports, it will be impossible to keep prices on a stable basis. Trade unionists are told that it is "no less a matter of direct self-interest than of social duty to help personally towards obtaining the substantial and sustained increase in production which will alone enable the unions to defend existing standards of life, and to secure necessary improvements in conditions of employment."

With questions relating to wages thus definitely disposed of, the main emphasis of the interim report is in the problem of control of prices. Beyond insisting that the subsidies must remain, the report offers no suggestions for further controlling prices, although specific proposals are promised in a final statement which is to be issued towards the end of this month for submission to a special conference of trade-union executives. "The General Council," it is stated, "is now proceeding to give detailed consideration to the methods by which, and the extent to which, the control of prices can be developed. This is by no means a simple problem in peace time. Physical controls operated by Government agencies are always likely to be less effective when industrial activities as well as the varieties of production must conform to a more diverse pattern than in war-time."

"The General Council," it is stated, "is not yet in a position, therefore, to report fully . . . on the conclusions it has reached regarding profits, prices, and inter-related questions. For these matters, the Government, of course, is directly and ultimately responsible, but the General Council is in touch with responsible Ministers in order to discuss them in all their aspects. In a final report, the General Council will present its views and proposals on questions which it regards as essentially within the sphere of Government responsibility."

The General Council appeals "to all workpeople, and particularly to trade unionists," to "do their utmost by individual and collective effort to increase production, and to support and encourage the drive for voluntary savings as a measure of prudence and foresight that will materially assist the country to overcome its present difficulties."

An editorial note in *Man and Metal*, the Journal of the Iron and Steel Trades Confederation, states that scrap is urgently needed by the industry. "It is estimated," the writer says, "that about 11,500,000 tons will have to be provided if the industry's production target for 1948 is to be fulfilled. We hope to obtain 1,000,000 tons of scrap from Germany, but doubts have recently been expressed in some quarters as to whether we shall be able to do so, and this gives an even greater sense of urgency to the scrap campaign sponsored by the British Iron and Steel Trades Federation. The Federation is to be congratulated on the vigour and resourcefulness with which it is conducting this campaign. It is no half-hearted effort, but a determined attempt to see that the industry's scrap requirements are met to the full. It deserves—and we wish it—complete success."

The Ministry of Labour and National Service estimates that in the eleven months, January to November, 1947, inclusive, changes in rates of wages resulted in an aggregate increase of 1,607,200*l.* in the weekly full-time wages of 1,632,500 persons. In addition, over 5,000,000 persons had their working week reduced by 3½ hours without any reduction of their wage rates for the shorter week. In the corresponding eleven months of 1946, there were increases of about 2,700,000*l.* in the weekly full-time wages of 7,600,000 persons. The principal group of persons affected by the wage changes in November, 1946, were in coal-mining, the building trades, civil-engineering construction, and the wholesale grocery and provision trade. In the 1947 period of eleven months there were 1,594 stoppages through industrial disputes involving 604,000 persons, and resulting in a loss of 2,355,000 working days.

Under a United Provinces Act to which the Governor-General of India has given assent, the daily hours of work for adults, exclusive of intervals allowed for rest and for meals, are restricted to eight, and the rates of pay for overtime work are fixed at twice the normal rates. The maximum permissible daily hours of work for children and young persons are fixed at six, and no employee is to be required to work for more than five hours without an interval of at least half an hour for rest or meals. In addition to a holiday of one whole day in each week, every employer is required to close his shop or commercial establishment on all days notified in the *Official Gazette* as holidays for Government treasuries. Every employee is to be entitled to 15 days' ordinary leave with pay if he has been in continuous employment for a period of one year, and to sickness leave with pay up to a maximum of 15 days.

TESTS OF RAILWAY BRAKE BLOCKS.

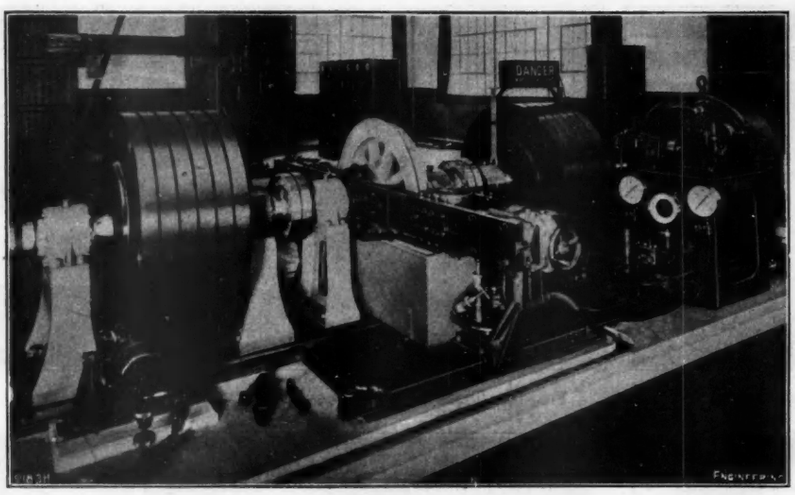


FIG. 15. TEST MACHINE.

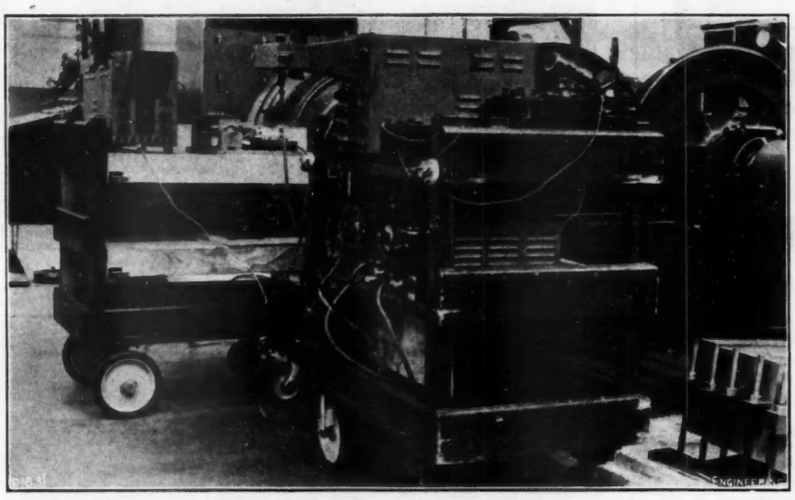


FIG. 16. ARRANGEMENT OF APPARATUS.

MEASUREMENT OF THE TEMPERATURE OF RAILWAY BRAKE BLOCKS.*

By DR. R. C. PARKER and DR. P. R. MARSHALL.

(*Concluded from page 22.*)

ALTHOUGH work has been done in the past on the interaction between railway brake blocks and tyres, many problems still remain unsolved. In particular may be mentioned the tyre deterioration which is initiated through heat-checks that are encountered on sections which have a high frequency of braking. The increased speed of trains, especially on suburban electrical services, has proved that, in the absence of new ideas on the subject, the economic limit of service of tyres and brake blocks will soon be reached. It was thought worth while, therefore, to apply the lead-sulphide cell pyrometer to the measurement of tyre surface temperatures, and to attempt to correlate the results with the variables speed, block pressure, and contact area.

This work was carried out with standard materials. Brake blocks normally supplied to the London, Midland and Scottish Railway are designated as type 1, and blocks supplied to the London Passenger Transport Board Railways as type 2. The cast-iron blocks were a standard type as fitted to the main-line railways. The railway wheel was a spoked type and the tyre, attached by a Gibson ring, was made to the specification: carbon, 0·40 per cent.; silicon, 0·25 per cent.; manganese, 1·45 per cent.; molybdenum, 0·48 per cent.; chromium, 0·65 per cent.; sulphur not to exceed 0·04 per cent.; phosphorus not to exceed 0·04 per cent.; and nickel not to exceed 0·07 per cent.

The machine on which this work was carried out is illustrated in Fig. 15, herewith. Its components comprise a 100-h.p. motor, two banks of flywheels, a railway wheel complete with tyre, and an articulated torque-arm arrangement carrying two brake blocks. One flywheel in each bank is fixed to the main shaft, and the remainder can be attached to the fixed flywheels, with the result that the number of flywheels in use may be varied from two to twelve. The pressure which applies the railway blocks is obtained from an oil cylinder which, in turn, derives its pressure from lead weights placed on a subsidiary oil ram. The torque arm is pivoted about its axis and is free to turn against suitably disposed oil cylinders connected to hydraulic recording gauges. The inertia of the rotating system, the brake-block pressure, and the angular velocity can be selected according to the service conditions which it is required to simulate. The speed range of the machine is from zero to 1,000 r.p.m. and the maximum energy at the highest speed is $4{\cdot}2 \times 10^6$ ft.-lb. The machine can be automatically operated at any required time cycle.

The surface temperature of the tyre was measured by directing the sighting tube normally to the surface. The radiation path used in calibration was matched by fitting a longer nose-piece to the sighting tube, and placing a piece of microscope cover slide glass over the cell aperture. Fig. 16, on this page, shows the general arrangement, and Fig. 8, on page 36, shows a close-up of the sighting tube and tyre. The cell and sighting tube are fixed to an adjustable mount which enables the cell to be set normal to the tyre surface, and to be traversed across the width of the tyre. The nose of the sighting tube was placed sufficiently close to the tyre to prevent any hot wear products being blown across its opening. It was also placed close to the end of the block so that at a speed of 60 m.p.h. only a 0·2 milli-second interval elapsed between the point of the tyre leaving the edge of the block and crossing the tube. Before the experiment was commenced the tyre was turned and ground. Its eccentricity was found to be 0·002 in. and its root mean square surface roughness, measured with a Brush surface analyser, was 57 micro-inches.

A camera was attached to the cathode-ray oscillograph and fitted with a drive which gave a film speed of 40 cm. per second. Since it was necessary to note which part of the tyre corresponded to any particular point in the temperature record, a deceleration and time-marking unit was connected to the Y2 beam of the cathode-ray oscillograph. In this unit, shown in Fig. 9, on page 36, a disc with 15 holes equally spaced around the circumference was positively driven by the shaft on which the railway wheel was mounted. A beam of light, which was directed through this disc on to a photo-cell amplifier unit, was thus interrupted 15 times per revolution of the wheel. A time scale was superimposed by interrupting a second light beam by means of a rod which was rotated about its centre at constant speed. The use of two light beams enabled the heights of the two traces to be varied.

Work by H. J. Schrader* on a cast-iron railway block has shown that the region over which contact occurs may be localised. This may effect the distribution of temperature, and hence it was decided to see whether the observed contact areas could be related to the observed tyre temperatures. A non-metallic material was taken and moulded round a number of copper probes so that they lay normal to the bearing surface, and were insulated one from the other. Each probe was connected to a 2-volt lamp in a panel and to the railway tyre by a low-tension battery. It was hoped that the lamps would indicate which regions of the block were contacting the tyre during a braking application. The method was checked by coating the block surface with chalk, making an application, and observing whether the area from which the chalk was wiped corresponded to the indication on the lamps. The method was successful with blocks of type 1, but failed with material of type 2, due to a differential movement that took place between the block material and the copper wire.

Interaction between blocks of type 1 and the ground tyre produced a characteristic discoloration of the steel. The appearance was a general darkening, which, on closer examination, revealed a structure very similar to that seen in finger-prints. Fig. 10, on page 36, is a panoramic photograph of half the circumference of the tyre taken after the first series of brake applications described below. It will be seen that contact with the tyre is only made at isolated raised spots that are roughly circular, with diameters varying from $\frac{1}{4}$ in. to 1 in. These localised areas are not uniformly distributed over the tyre surface, but form in clusters between the spokes on the wheel (the white rectangles in Fig. 10 denote the spoke positions). The size of the clusters vary round the tyre, and correspond to the degree of its eccentricity. Figs. 11 and 12, on page 36, show the appearance of the clusters at the extremities of one diameter. Irregularities are also observed across the width of the tyre, and Fig. 13, on page 36, suggests the non-uniform expansion of the tyre from the flange to the inner rim. These features have been observed for wide variations in braking conditions, although after some thousands of braking applications the clusters eventually spread until they merge together to give a uniform pattern. The general behaviour then is that the tyre tends to bulge between the spokes, and that further raised areas develop on the bulges. Fig. 14, on page 36, shows the surface of the tyre after brake applications had been made with cast-iron blocks.

Confirmatory evidence of these localised contact areas was obtained from the indicating lamps. Not only was the number of lamps which lit up at any instant small, but their number and position also varied with great rapidity during a braking application. The effect of irregular tyre surface on the block contact area was sought by chalking the blocks and photographing the contact areas for full and momentary braking applications over a wide range of braking conditions. Despite the fact that hundreds of photographs were analysed, the picture which emerges was confused. It was clear, nevertheless, that the area of the block which contacts the tyre moves during an application and is at any instant extremely small.

* Paper entitled "The Measurement of the Temperature of Sliding Surfaces, with particular reference to Railway Brake Blocks," read at a meeting of the Institution of Mechanical Engineers, held in London on November 7, 1947. Abridged.

* "The Friction of Railway Brake Shoes at High Speed and High Pressure." *Univ. of Illinois Bulletin*, vol. 35, No. 72 (1938).

TESTS OF RAILWAY BRAKE BLOCKS.

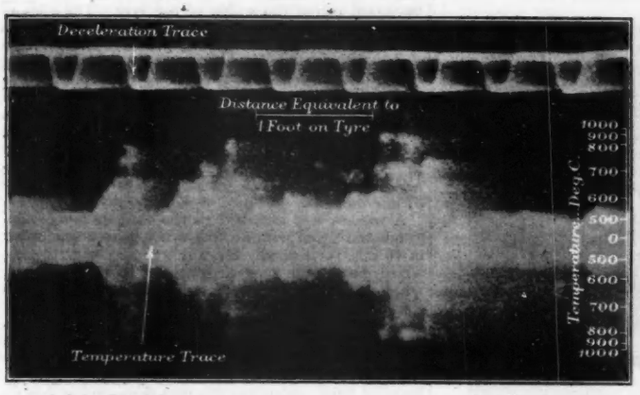


FIG. 17. VARIATION OF TEMPERATURE ALONG TYRE CIRCUMFERENCE.

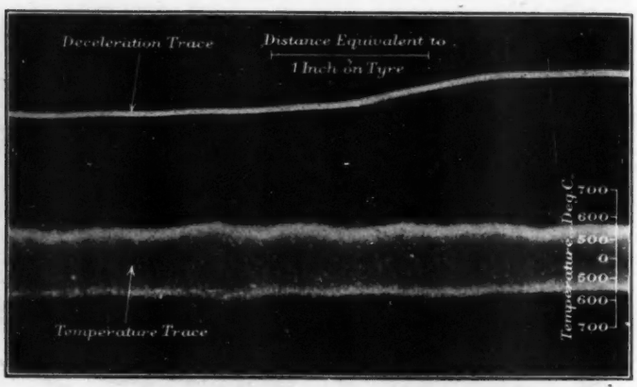


FIG. 18. TYRE TEMPERATURE AT END OF BRAKING APPLICATION.

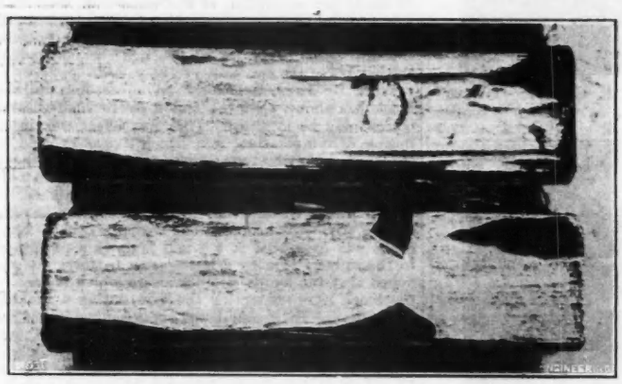


FIG. 19. CONTACT AREAS FOR NORMAL BLOCK.

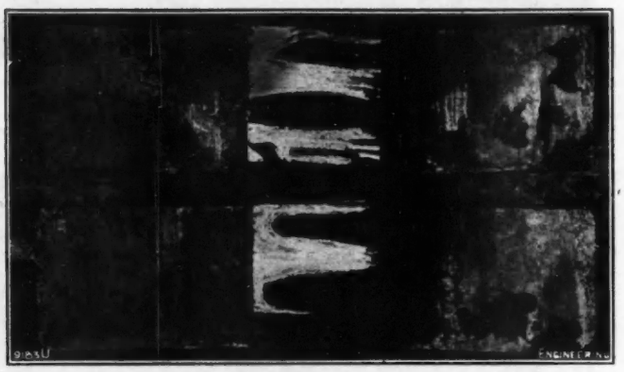


FIG. 20. CONTACT AREAS FOR QUARTER-SIZE BLOCK.

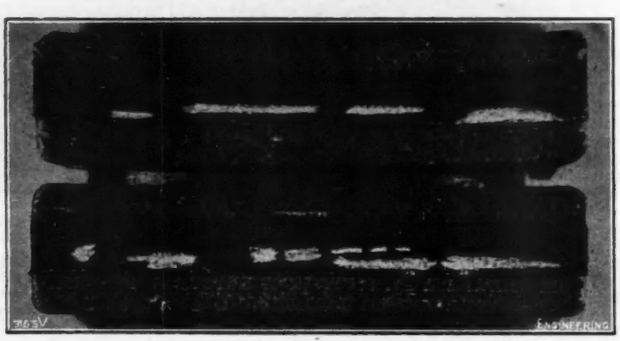


FIG. 21. CONTACT AREAS FOR BLOCK CUT TO PRODUCE "STRIP" BRAKING.

As an example, a full braking application from a speed of 60 m.p.h. at a pressure of 1,240 lb. gave a contact area in the order of 15 per cent. It was also apparent that the area of contact during any one application tended to be confined to one or more narrow strips running along the block length. That the position of these strips was due to tyre distortion was evident from the fact that the areas of contact for both the leading and trailing blocks were similar in extent and position.

In the first series of experiments, values of surface temperature were determined for different values of the kinetic energy dissipated. Braking applications were made every two minutes from 60 m.p.h. at pressures of 1,240 lb. and 3,560 lb. Three values of kinetic energy were used, namely, 3×10^6, 6×10^6, and 12×10^6 ft.-lb. Table I, opposite, shows the results for blocks of type 1 and type 2. Blocks of type 2 have a higher coefficient of friction, as is shown from the energy dissipation rates. The variation of energy dissipation rates was attributed to the fact that, as the general level of tyre temperature rose, the coefficient of friction fell. This phenomenon is generally known as temperature fade. The magnitude of the observed temperature depended on whether or not the sighting tube was in line with that portion of the block which was making contact with the tyre, and hence readings are tabulated to show a number of applications at which temperatures greater than 200 deg. C. (390 deg. F.) were attained, and the distribution of these temperatures within the three arbitrary temperature ranges. The oscillograph deflections were read visually, and the camera used to record different types of temperature variation. Over a number of applications, the recorded temperature increased with the kinetic energy dissipated. Furthermore, as the kinetic energy increased, so did the number of readings in the higher temperature ranges. The temperature ranges were frequently very high, and, during one series of braking applications with type 1 material at a pressure of 3,560 lb., 60 per cent. of the total number of braking applications gave a temperature greater than 800 deg. C. (1,470 deg. F.).

Although the highest temperatures attained are not shown in Table I, it was frequently estimated that they were in the order of 1,500 deg. C. (2,730 deg. F.). The manner in which the temperature varied along the tyre circumference is shown in Fig. 17, on this page, from which it may be seen that the temperature gradient may be as high as 142 deg. C. (287·6 deg. F.) per inch circumferentially. The temperature over one half of the circumference was also observed to be much greater than over the other half, which confirms previous observations on tyre eccentricity. Observations on a second cathode-ray oscillograph connected in parallel with the first, show wide variations in general behaviour. The maximum temperature, for example, would occur at any time from the beginning to the end of a stop. At the end of one braking application a record was obtained of the high temperature just as the wheel came to rest (Fig. 18), at which moment the tyre temperature was also recorded near the sighting tube by means of a Cambridge Instrument Company's tab-type thermocouple. The temperature indicated by the thermocouple was 200 deg. C. (390 deg. F.), while that indicated by the film was 575 deg. C. (1,067 deg. F.). This discrepancy may be attributed either to the disturbance of high temperature gradients by conduction of heat along the thermocouple, or to poor thermal contact between the thermocouple and tyre.

A second series of experiments was made to differentiate between the effect of the energy dissipation rate, angular velocity, and pressure at constant values of the kinetic energy, on the incidence of high localised temperatures. The energy dissipation rate is proportional to $\omega\mu P$, where ω is the angular velocity, μ the coefficient of friction, and P the brake-block pressure; μ varies with P, so that a clear differentiation between the three variables cannot be made, but it was thought probable that careful consideration might indicate the general trend. The results are shown in Table II, opposite, from which it seems that there is no marked variation of temperature over a wide range of speeds and pressures. Conclusive results, however, cannot be drawn, owing to the small number of braking applications made.

Results so far described have shown that the area of contact between the block and tyre is very small and moves along longitudinal strips that lie parallel to the length of the block. It may be objected that the chalk method does not indicate the true area of contact, since areas may have been swept free from chalk by only intermittent point contact. Conversely, other areas may have had points of contact of insufficient magnitude and too wide apart to remove the chalk to a visible degree. It seems probable, however, that the lower flow pressure of the non-metallic block will yield concentrated rather than dispersed areas of contact, while the manner in which the results fit together suggests that any such discrepancy does not invalidate the general picture. For any given set of conditions, the actual contact area should be a function of the block material and block pressure and its position within the block face might be expected to vary with the ratio of the block length to the block width. Evidence on this point was sought by carrying out a series of experiments with a block progressively shortened to give three-quarters, one-half, and one-quarter of the original area. Braking applications were made with blocks of type 1 and type 2, and also of cast iron,

TESTS OF RAILWAY BRAKE BLOCKS.

Fig. 22.

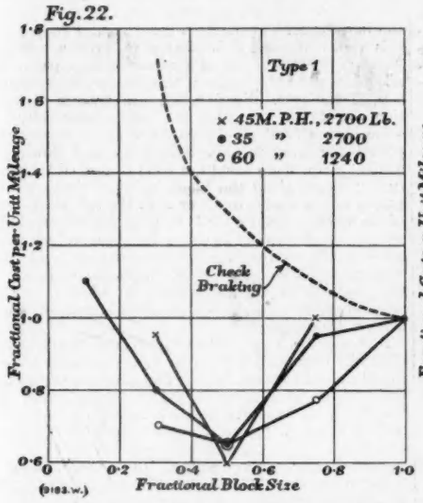


Fig. 23.

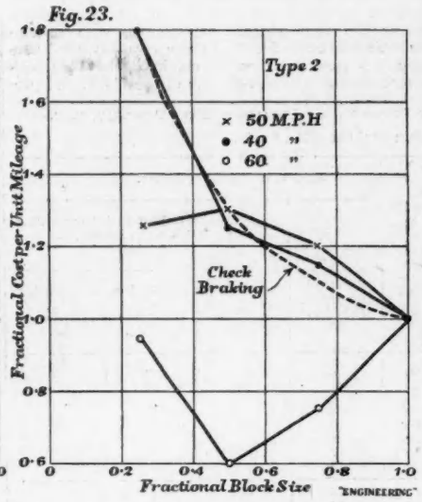


TABLE I.—EFFECT OF KINETIC ENERGY ON INCIDENCE OF LOCALISED HIGH TEMPERATURES.

Velocity, 60 m.p.h.; brake block pressure, 1,240 lb.; braking cycle, 2 min.

Brake Block Material.	Kinetic Energy Dissipated, Ft.-lb.	Energy Dissipation Rate, 10^6 ft.-lb. per Min.		No. of Brake Applications.	Visual Indication of High Temperature.†	Maximum Tyre Temperature.			
		Min.	Max.			No. of Applications During which Temperature Exceeded 200 deg. C. (390 deg. F.).	Distribution of Recorded Temperatures over 200 deg. C. (390 deg. F.) (Percentage). 200-400 deg. C. (390-750 deg. F.).	400-800 deg. C. (750-1,470 deg. F.).	Over 800 deg. C. (1,470 deg. F.).
Type 1 ..	3×10^5	1·6	1·9	23	No	5	100	—	—
	6×10^5	0·8	1·6	50	No	8	50	50	—
	12×10^5	0·9	2·0	20	Yes	11	54	36	10
	6×10^5	0·6	1·8	38	Yes	21	49	37	14
	12×10^5	0·8	1·7	20	Yes	12	25	60	25
	12×10^5*			6	Yes	6	—	33	67
Type 2 ..	3×10^5	2·0	2·3	60	Yes	17	65	35	—
	6×10^5	2·0	3·0	50	Yes	29	27	52	21
	12×10^5	2·6	3·1	16	Yes	12	69	25	6

* Brake-block pressure, 3,560 lb. † Seen as a red-hot streak round circumference.

TABLE II.—EFFECT OF ENERGY DISSIPATION RATE, VELOCITY, AND PRESSURE ON INCIDENCE OF LOCALISED HIGH TEMPERATURES.

Material, type 1; kinetic energy dissipated (at 30 m.p.h.), 3×10^5 ft.-lb.; braking cycle, 2 minutes.

Velocity, m.p.h.	Brake-Block Pressure, Lb.	Energy Dissipation Rate, 10^6 ft.-lb. per Min.		No. of Brake Applications.	Visual Indication of High Temperature.	Maximum Tyre Temperature.			
		Min.	Max.			No. of Applications During which Temperature Exceeded 200 deg. C. (390 deg. F.).	Distribution of Recorded Temperatures over 200 deg. C. (390 deg. F.) (Percentage). 200-400 deg. C. (390-750 deg. F.).	400-800 deg. C. (750-1,470 deg. F.).	Over 800 deg. C. (1,470 deg. F.).
30	1,240	0·5	1	40	No	6	83	17	—
30	3,560	1·2	2·4	46	No	7	43	57	—
42·5	1,825	0·8	1·2	43	No	14	93	7	—
—	—	1·6	1·9	23	No	5	100	—	—
60	1,240	0·8	1·6	50	No	8	50	50	—

at initial speeds of 60 and 30 m.p.h., a brake-block pressure of 1,240 lb., and a two-minute cycle. The results are shown in Table III, on page 48. Reduction in block length for types 1 and 2 is accompanied by a reduction in maximum tyre temperature, so that, on braking from 60 m.p.h., the block one-quarter of the original size gave a maximum tyre-surface temperature under 400 deg. C. (750 deg. F.) for types 1 and 2 material. Reduction in the length of cast-iron blocks produced no decrease in temperature.

Reduction in the length of non-metallic blocks was accompanied by a characteristic change in the region of contact area. Figs. 19 and 20, opposite, show typical patterns for the full-size and the quarter-size block, respectively, from which it will be seen that the longitudinal strips have given place to areas crossing the full width of the block. That high temperatures are associated with longitudinal strips was confirmed by cutting away the block so that only the central strip remained, one-third of the original size. Brake applications were made from 30 m.p.h., at a pressure of 1,240 lb., and a kinetic energy of 3×10^5 ft.-lb., when every application gave temperatures greater than 800 deg. C. (1,470 deg. F.). The area of contact for this block is shown in Fig. 21, opposite. In this series of experiments, the general tyre temperature was measured by means of the tab-type thermocouple instrument. The thermocouple was applied immediately the wheel came to rest, and measurements were made at one of three points equally spaced around the circumference. A plot of these results against the number of applications indicates that the general temperature was not affected by the block size. This is to be expected, since equilibrium would be attained between the heat lost through conduction, convection, and radiation, and the heat supplied by the dissipation of kinetic energy.

The decrease in high localised temperatures effected by shortening the non-metallic blocks was accompanied by a change in both friction and wear characteristics. Table IV, on page 48, shows the standard deviation σ for the stopping times of the wheel when braking from initial speeds of 30 m.p.h. and 60 m.p.h. by blocks of types 1 and 2 under a pressure of 1,240 lb. The final column is given to facilitate comparison of the deviation irrespective of the value of the stopping time.

Two additional advantages are seen to accrue from the shorter block: scatter in stopping time is less, and there is less temperature fade. Table V, on page 48, illustrates how wear of type 1 blocks varies with block size at various speeds and pressures. The wear was obtained by weighing the blocks before and after 350 braking applications and expressing the loss in grammes. Expressing the wear of the shortened block on a thickness basis, as a fraction of that of the normal block, shows that the normal and half blocks wear at exactly the same rate. Further decrease in size results in faster wear on a thickness basis. In the last column of Table V is tabulated the fractional cost of the block per unit mileage, and the plot of this quantity against the size of the block expressed as a fraction of the normal size is given in Fig. 22, on this page. It will be seen that the cheapest block is, on this basis, only one half the present standard size, although the exact shape of the curve depends upon the relation between the manufacturing cost of a block and its size. The dotted line on the graph is calculated on the assumption that the loss in weight is constant irrespective of the block size, a condition which is likely to hold under check braking applications. The size of block which gives the lowest cost per unit mileage is obtained from the integration of a family of such graphs taken over all such possible conditions. In deciding the optimum block size, consideration must be given to reblocking costs, to tyre conditions, and to other similar factors; thus, on the basis of tyre conditions, the optimum block size for material types 1 and 2 is approximately a quarter-sized block. In Fig. 23, on this page, is shown a similar graph of fractional costs per unit mileage against fractional size, for material of type 2, in which the cost per unit mileage increases as the block is reduced in size, and so confirms that each block material must be treated individually. In this case, the brake-block pressure is 1,240 lb., and, as before, the braking cycle is 2 minutes and the kinetic energy is 12×10^5 ft.-lb.

The results given in Table III show that, as the block size is reduced, so is the incidence of high tyre-surface temperatures. As it is high tyre-surface temperature which leads to the formation of "heat-spots," and finally cracks, the possibility of avoiding this type of tyre failure was investigated. The tyre was reground and brake applications made with blocks of type 1, having a face area of 11·5 sq. in., from 60 m.p.h. at a block pressure of 1,240 lb., and kinetic energy of 12×10^5 ft.-lb. After 400 applications, during which the wheel was cooled after each 25, the tyre was examined. Only eight spots had appeared and these were badly defined and difficult to see. They were not heat-spots in the usual sense, in that they were softer than the rest of the tyre. The hardness was measured with a Scleroscope; that of the freshly ground tyre was 42, the mean hardness of the above spots was 36, and the mean hardness of the rest of the tyre was 41. The soft spots are thought to arise from hard heat-spots which were not completely removed during grinding. During the experiment, the general temperature of the tyre was sufficient to temper the martensite of the hard heat-spots, which thus gave rise to areas of sorbite, the hardness of which is less than that of fine-grained pearlite, the structure of the rest of the tyre. The hardness of the tyre, as ground and after testing, shows that the use of the small block had no effect on the structure of the tyre material. Four hundred brake applications were next made under exactly the same conditions as before, except that a full-size block was used. At the conclusion of the test, the tyre had developed numerous heat-spots. The hardness of these (mean of 50 readings) was 70 Scleroscope. The hardness of the metal comprising the rest of the tyre was 54 Scleroscope. Cracking of the tyre is known to develop from the heat-spots; possibly it is initiated by the volume changes which occur on the formation and subsequent tempering of martensite.

These results also prove, conclusively, the truth of the assumption that the temperature indicated on the oscillograph is not very different from that under the brake block. In the case of the full block, the oscillograph showed 25 per cent. of the readings corresponding to a temperature over 800 deg. C. (1,470 deg. F.), and in this case heat-spots are produced on the tyre. In the case of the quarter block, the oscillograph showed no temperature indication above 400 deg. C. (750 deg. F.) and no heat-spots were produced on the tyre. The evidence supplied by the metallurgical investigation is thus in complete agreement with that gained from this method of measuring surface temperature.

Examination of surface conditions in railway brake blocks shows that, under standard conditions, the initial application of the brakes results in only small localised contact areas between the block and tyre. The block and tyre undergo thermal expansion over the localised areas, with the result that contact is confined to one or more thin strips along the length of the block. Dissipation of the entire kinetic energy in these restricted areas produces tyre distortion of great

complexity. Large bulges form between the spokes of the wheel, and smaller raised areas are visible on the bulges. These areas of contact are further modified by tyre eccentricity, and other distortions. As the raised areas of the block are worn away, further areas come into contact, with the result that the strip contact areas tend to move to and fro across the block.

Surface temperature measurement shows that the temperature of the raised areas of the tyre increases with the kinetic energy dissipated, and, for conditions which may be regarded as moderate in service, temperatures greater than 800 deg. C. (1,470 deg. F.) are registered. Existence of these high temperatures has been shown to cause inconsistency in the kinetic coefficient of friction, to initiate rapid wear of the block, and to produce heat-spots on the tyre, that ultimately develop into cracks. General considerations show that the contact area of the block is constant under a given set of conditions, so that, if the above theory is correct, progressive shortening of the length to width ratio of the block should result in a point being reached at which the area of contact must spread across the tyre width. Experiments with a non-metallic block smaller than those normally used confirm this view, as their use eliminates localised high temperatures, increases the life of the block, and produces greater uniformity in friction. Confirmation of decrease in temperature was obtained by the absence of structural changes in the steel, with the consequent elimination of thermal cracks. The optimum length to width ratio varied with the block material, being in general greater the higher the degree of plasticity. The contact area of the cast-iron block, for example, is so small that the elimination of high temperatures would require a very small length to width ratio. The life of such a block would be unserviceably small.

It may be objected that, even with a shortened block, high surface temperatures still occur under the block, and that it is misleading to measure temperatures at the block edge. There is no experimental support for this view; indeed, it is clear that, from a practical point of view, the measurements in this paper are adequate, since they agree with metallurgical examination of the tyre. Further, the temperature distribution round the circumference was substantially the same over several revolutions, and since during this period the contact area moved up and down the contact strip, there could not exist a marked temperature gradient along the block length. If the plastic nature of the block, together with the spherical shape of the small bulges on the tyre, yield concentrated and not dispersed areas of contact, the measured temperatures would be the true temperatures even at high sliding velocities. This work shows no evidence of temperatures in the neighbourhood of the melting point of the tyre steel, once the size of the brake block is correctly designed.

Although Dr. L. K. Sillcox* postulated the existence of locally expanded regions on tyre treads, this work would appear to provide their first direct experimental proof. Sillcox's suggestion of a corrugated tread surface, with undulations regularly spread, is an over-simplification as far as a spoke wheel is concerned, although a tyre on a solid disc wheel is less likely to form the larger primary bulges. In any case, observations on the tyre indicate that thermal cracks initiate on the smaller bulges. It is concluded, therefore, that, once the surface temperature is lowered below the change point of the steel by the use of a non-metallic block of correct dimensions, this form of tyre deterioration will not occur.

TABLE III.—EFFECT OF BEARING SURFACE AREA ON INCIDENCE OF LOCALISED HIGH TEMPERATURES.

Brake block pressure, 1,240 lb.; braking cycle, 2 min.

Brake-block Material.	Velocity, m.p.h.	Bearing Surface Area, Sq. in.	Kinetic Energy Dissipated, 10^5 ft.-lb.	Energy Dissipation Rate, 10^6 ft.-lb. per Min.		No. of Brake Applications.	Visual Indication of High Temperature.	Maximum Tyre Temperature.			
				Min.	Max.			No. of Applications During which Temperature Exceeded 200 deg. C. (390 deg. F.).	Distribution of Recorded Temperatures over 200 deg. C. (390 deg. F.) (Percentage).		
									200-400 deg. C. (390-750 deg. F.).	400-800 deg. C. (750-1,470 deg. F.).	Over 800 deg. C. (1,470 deg. F.).
Type 1	30	46	3	0·5	1	40	No	6	83	17	—
		34·5	3	0·9	0·9	60	No	18	55	45	—
		23	3	0·7	0·8	50	No	None	—	—	—
		11·5	3	0·6	0·8	40	No	None	—	—	—
	60	46	12	0·8	1·7	20	Yes	12	25	60	25
		34·5	12	1·0	1·4	31	Yes	14	21	57	22
		23	12	0·8	1·0	30	No	17	100	—	—
		11·5	12	0·8	1·2	30	No	19	100	—	—
Type 2	60	36	12	2·6	3·1	16	Yes	12	69	25	6
		18	12	2·4	2·9	20	No	13	75	25	—
		9	12	2·3	2·7	13	No	9	100	—	—
Cast iron	60	43	12	1·0	1·7	20	Yes	18	69	31	—
		21·5	12	1·0	1·5	20	Yes	19	—	100	—
		11	12	—	—	16	Yes	16	—	100	—

TABLE IV.—EFFECT OF AREA OF BLOCK FACE ON CONSTANCY OF STOPPING TIMES.

Brake-block pressure, 1,240 lb.; braking cycle, 2 min.

Area of Block Face, sq. in.	Velocity, m.p.h.	Kinetic Energy Dissipated, 10^5 ft.-lb.	Statistical Analysis of Stopping Times,* Readings No.	Mean Stopping Time, sec. M.	Standard Deviation of Stopping Times, sec. σ.	$\frac{\sigma}{M}$
Material, type 1.—						
46·4	30	3	1–26	28·0	6·67	0·242
			27–51	35·5	9·08	0·255
			1–51	31·7	8·78	0·277
	60	12	1–16	62·3	10·6	0·170
			17–31	92·0	14·0	0·152
			1–31	76·7	19·1	0·249
34·8	30	3	1–51	36·8	4·30	0·117
			27–51	39·4	1·21	0·0308
	60	12	17–16	59·3	11·4	0·192
			1–31	74·7	10·6	0·142
			1–31	66·8	8·89	0·133
16·6	30	3	1–51	39·0	1·81	0·0465
			27–51	40·2	1·13	0·0281
	60	12	1–16	67·8	10·6	0·156
			17–31	68·9	5·99	0·087
			1–31	68·3	8·67	0·0127
11·6	30	3	1–51	39·6	4·99	0·126
			27–51	43·4	1·68	0·0388
	60	12	1–31	69·2	8·67	0·125
Material, type 2.—						
37	30	3	1–51	16·1	1·02	0·0634
	60	12	1–31	28·9	3·25	0·112
27·75	30	3	1–51	14·0	0·417	0·0298
	60	12	1–31	28·4	1·89	0·0666
18·5	30	3	1–51	12·0	0·376	0·0313
	60	12	1–31	27·4	1·41	0·0515
9·25	30	3	1–51	12·9	0·522	0·0405
	60	12	1–31	26·2	1·46	0·0558

* A reading of the stopping time is recorded for every alternate stop.

TABLE V.—EFFECT OF BEARING SURFACE ON FRACTIONAL COST PER UNIT MILEAGE.

Material, type 1; kinetic energy dissipated (at 60 m.p.h.), 12×10^5 ft.-lb.; braking cycle, 2 min.

Block Pressure, lb.	Velocity, m.p.h.	Block Area, sq. in.	Block Wear, Grammes per 350 Applications.	Block Wear per Unit Area, Grammes per sq. in.	Fractional Rate of Wear, Thickness Basis.	Fractional Cost of Block.	Fractional Cost per Unit Mileage.
2,700	35	46	30	0·65	1	1	1
		34·5	26	0·755	1·16	0·82	0·95
		23	15	0·65	1	0·64	0·65
		11·5	13	1·13	1·74	0·45	0·80
		5·75	14	2·43	3·75	0·20	1·10
2,700	45	46	71	1·54	1	1	1
		34·5	63	1·82	1·18	0·82	1
		23	34	1·48	0·96	0·64	0·60
		11·5	37·5	3·26	2·12	0·45	0·95
1,240	60	46	147	3·20	1	1	1
		34·5	105	3·05	0·94	0·82	0·77
		23	73·5	3·20	1	0·64	0·65
		11·5	57	4·95	1·55	0·45	0·70

* *Mastering Momentum.* Simmons-Boardman Publishing Corporation, New York (1941).

CATALOGUES.

Lifting and Handling Equipment.—A catalogue received from the Vaughan Crane Company, Limited, Openshaw, Manchester, 11, describes and illustrates a wide range of overhead electric travelling and Goliath cranes, control systems, telphers, hoist blocks, overhead hand-power cranes, pulley blocks, overhead runways, and self-landing warehouse hoists.

Automatic Lathes.—The five-spindle bar and chucking automatic lathes of Messrs. A. C. Wickman, Limited, Tile-hill, Coventry, are described in a catalogue to hand from the firm. Interchangeable cams, which waste time during setting, are eliminated, and replaced by patented quadrant-linkage mechanisms which effect alterations in the working strokes by simple sliding adjustments.

Plug Pillars and Plug Boxes for Power Supply to Cranes.—A brochure recently issued by Messrs. Johnson and Phillps, Limited, Victoria-way, Charlton, London, S.E.7, gives a well-illustrated account of the crane plug pillars and plug boxes manufactured by them for use on dock, quays and railway sidings. These pillars are of different designs and include the tandem type for use where power is to be supplied to cranes on both sides of a wharf or siding simultaneously; and another in which a fully-interlocked isolator switch is incorporated. Details of feeder and section pillars are also given; the plug boxes illustrated are suitable for installation both in and out of doors.

Private Automatic Telephone Facilities.—Three leaflets recently issued by the Automatic Telephone and Electric Company, Limited, Strowger Works, Liverpool, 7, describe special services which are now available to users of Strowger private automatic telephone exchanges. The first of these is a "key-calling" service, which enables an executive to establish contact with anyone of ten or more principal officers, even if the required line is engaged at the time. The second provides for giving fire-alarm signals from any telephone position; while the third is a code calling service which enables communication to be established with any senior officer, who is not in his office, by flashing lamps or signalling bells.

Electrical Wiring Conduit Fittings and Accessories.—The twenty-first edition of a catalogue covering every type of conduit for electric wiring, as well as the associated fittings and accessories, has been issued by the General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2. As this publication runs to 200 pages, the comprehensive index, which is designed to assist the contractor to find the most suitable equipment for the work in hand will prove useful. Another feature, which appears for the first time, is a section devoted to the weights and dimensions of conduit fittings; this includes dimensioned drawings of all the principal fittings. Tables for the conversion of lengths and weights to the metric system may also be commended as an aid to the export drive.